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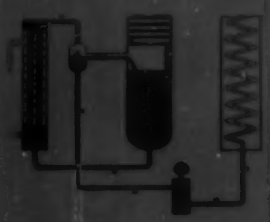
JUNE 1959



SAFE operating practices in air and ammonia plants... page 54

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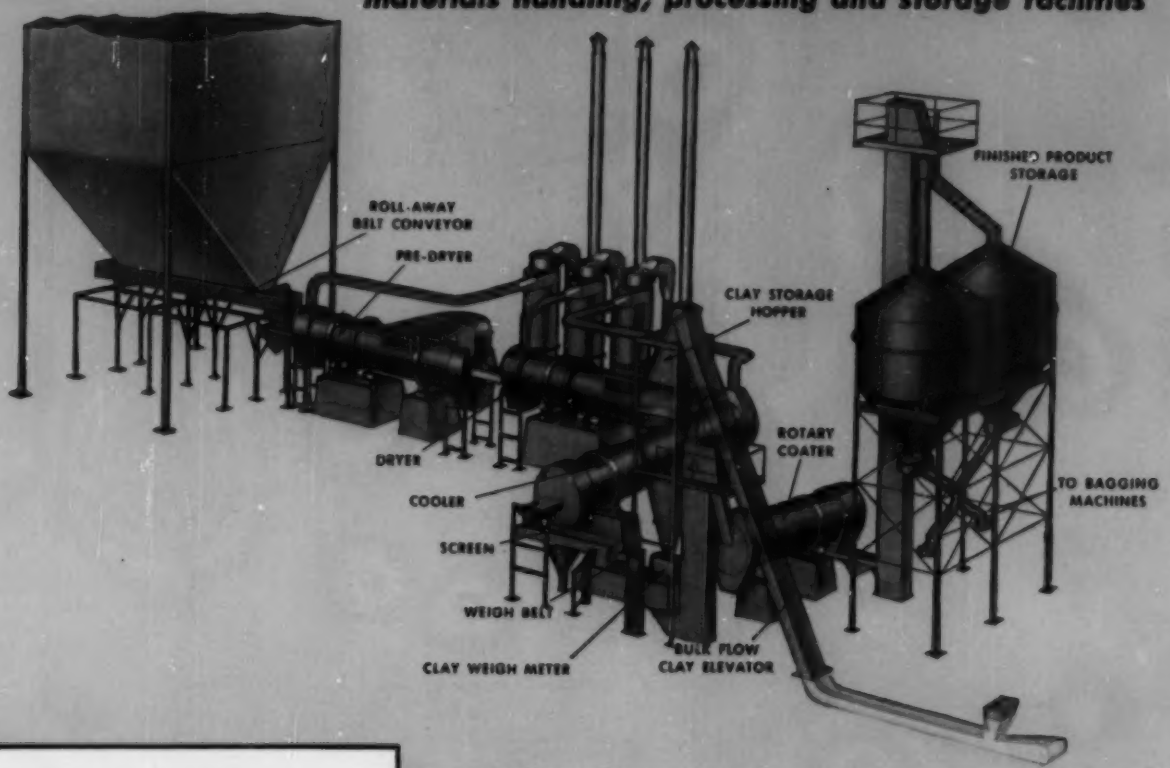

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Cover by Paul Arlt.

.... in this issue

Processes	49, 54, 84, 108, 116, 134	Meetings	114, 140, 148
Design	65, 71, 76	A.I.Ch.E.	114, 140, 148, 162
Equipment	49, 71, 74, 108	Materials	16
Economics	15, 17, 33, 37, 38	Foreign	37, 38, 41, 45
Management	35, 41, 45	Government	38, 45
		Careers	17, 35

Under the deadline 15

Scope—Engineering teaching salaries continue climb . . . First data on ethylene-propylene copolymer . . . Students advised to diversify.

Really out of the Recession? 33

Trends—Sharp gains in earnings reported by many chemical firms in first quarter.

Recognition for the Engineer 35

Opinion & Comment—If engineering talent in the U.S. is to be kept at engineering tasks, we shall have to recognize its worth.

Special CEP feature — **International Licensing**

International Licensing—Safeguard or Roadblock? 37

Ralph Landau—To the chemical industry, with its huge research and development expenditure, its shifting markets, and its fast-moving price structure, the problems of international licensing and collaboration are acute.

Technical Export Data Control 38

R. H. Meyer—An authoritative exposition of the new Government export control regulations for technical data by a Dept. of Commerce expert.

Progress Through Licensing 41

W. C. Asbury—The ready availability of efficient processes through licensing has contributed much to cost control in the petroleum industry.

The Law and Foreign Licensing 45

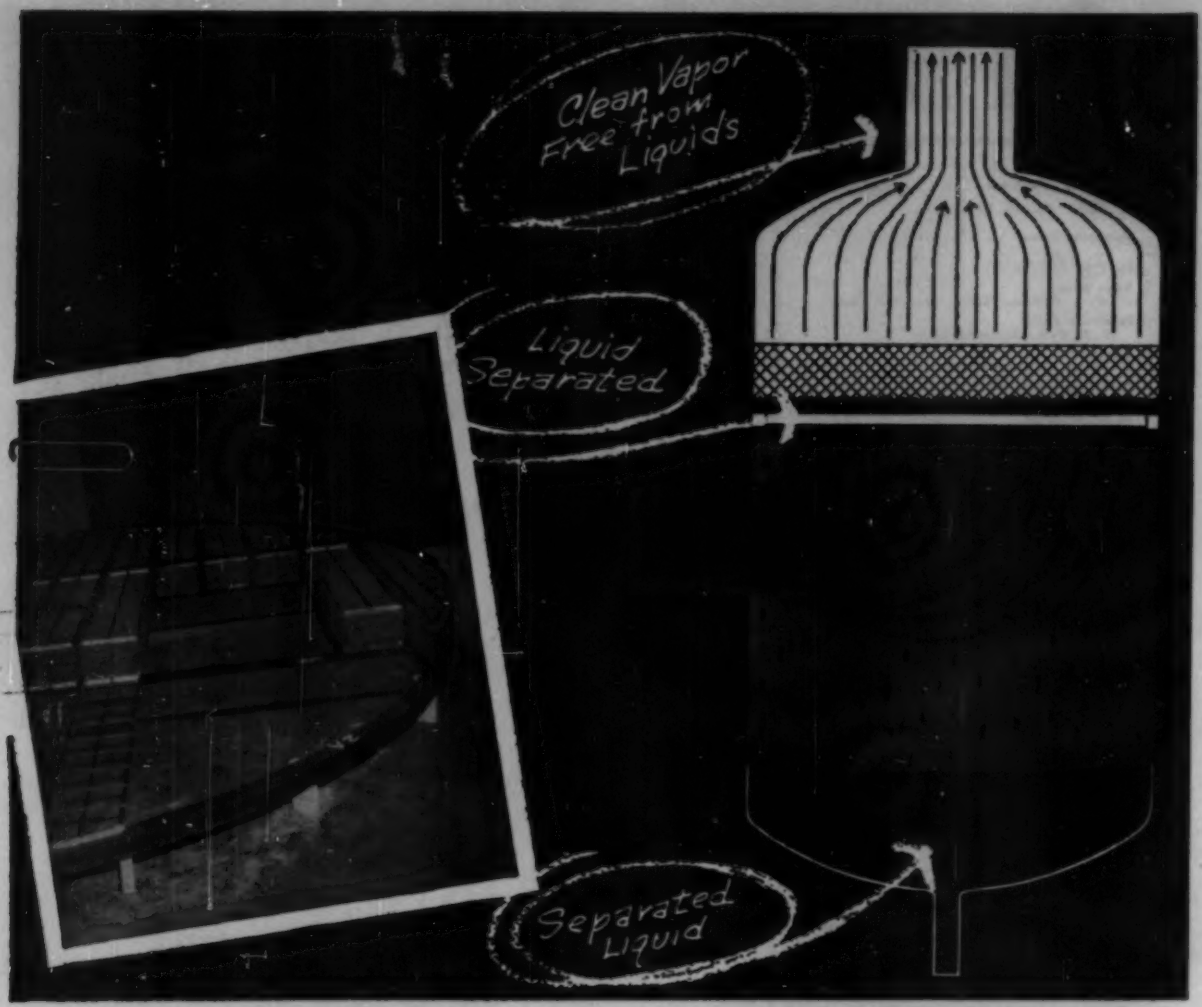
T. G. Gillespie, Jr.—An insider's view by a practicing lawyer-engineer.

High Speed Photography for Chemical Engineering 49

J. W. Westwater—A review of five papers on analysis by photography of rapidly occuring chemical engineering phenomena.

(Continued on page 5)

For more information, circle No. 4



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CEP .... in this issue

(Continued from page 3)

Safety in Air and Ammonia Plants 54
A roundtable—First of three installments of a transcript of discussions at the 1958 A.I.Ch.E. Meeting in Salt Lake City.

Non-Linear Engineering Models 65
D. W. Marquardt—Introduction to a technique which is assuming increasing importance in chemical engineering.

Thermal Surface Fouling 71
D. Q. Kern & R. E. Seaton—Calculation of a mathematical relationship between allowable pressure drop and accumulation of fouling with time.

Air Cooled Heat Transfer Equipment 74
J. F. Todd—Procedures and techniques for field performance testing.

Kinetic Analysis of Naphtha Reforming 76
R. B. Smith—A simplified method of calculation for operating conditions, number of reactors, catalyst bed sizes.

What's Doing in Industry 84
"Ultimate" fuel in production . . . Continuous tar distillation in Canada . . . Fuel reprocessing at Oak Ridge.

Chromatographs Can Save Money 108
Use in refining and petrochemical operations offers stepped-up efficiency, substantial cost savings.

Waste Treatment in a Modern Refinery 116
Details of the biological oxidation system at Cities Service Oil's new Bronte, Ontario, refinery.

CEP Camera 126
Kansas City round-up, plus unusual industrial shots.

Heat Transfer Conference 128
Complete technical program of joint A.I.Ch.E.-ASME Storrs, Conn., heat transfer meeting, August 9-12, 1959.

Computer Program Abstracts 134
Second installment of a continuing CEP feature.

St. Paul in September 140
Where to go, what to see.

departmental features

What they're saying—8 • Scope—15 • Marginal Notes—22 • Authors—24 • Trends—33 • Opinion & Comment—35 • Data Service—95 • Candidates—112 • Meetings—114 • CEP Camera—126 • Local Sections—146 People—152 • Advertiser's Index—161 • News & Notes—162

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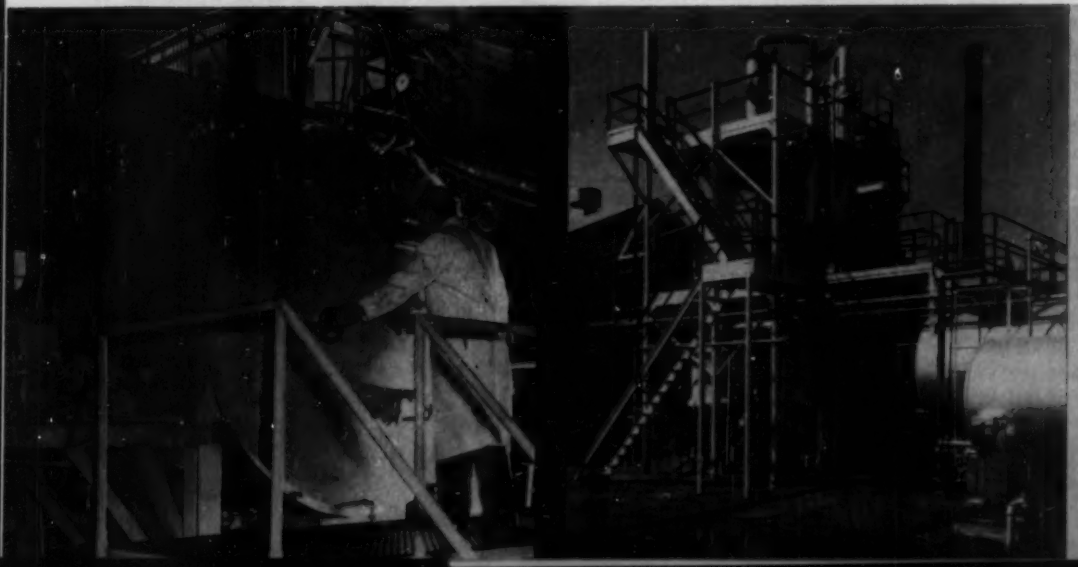
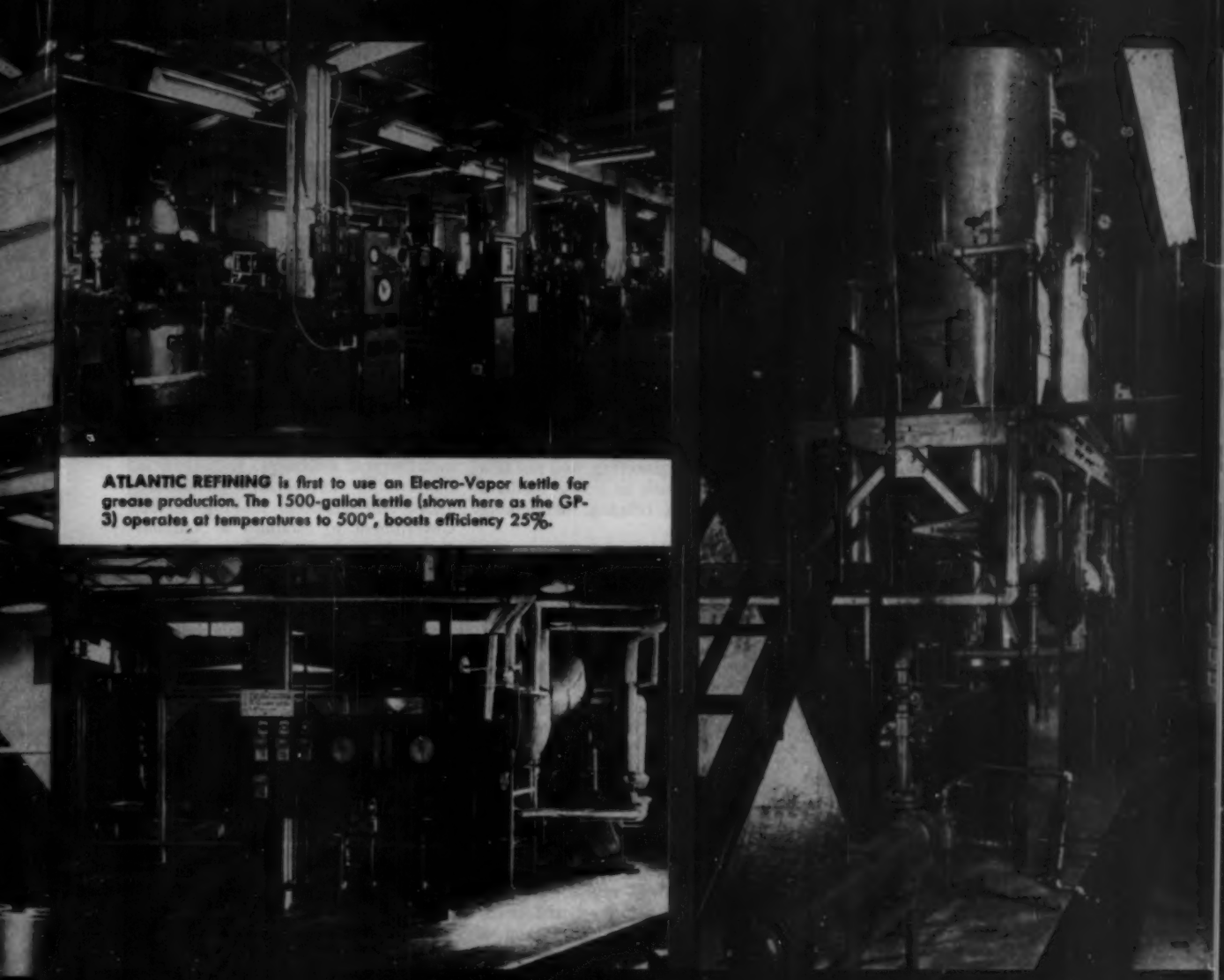


Right:
BARECO WAX COMPANY, Division of Petrolite Corporation, uses two single effect, downflow evaporators at Barnsdall, Okla. Shown here: the 235 sq. ft. evaporator.

Left:
PILOT PLANT vacuum double drum dryer is part of modern equipment developed at the Buflovak customer service laboratory—a completely equipped product-process research center.



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Chemical Engineering in the next decade

LAUREN B. HITCHCOCK
New York, N. Y.

Chemical engineering education has matured a great deal since I taught it 25 years ago. Emphasis then was on a series of Unit Operations. The list was growing. Then a common denominator was found for many of them. It started through the invention of dimensionless groups in the early thirties, aided and abetted by Tom Chilton, then director of the Du Pont Experiment Station, and professors at MIT, Columbia, Michigan and other emporia of higher learning. As a result, the Unit Operations became simplified into a few basic groups—as we understood their underlying fundamentals. We talk now more and more of Rate Processes—as the equations governing mass, momentum and heat transfer are shown to be parallel processes, akin to chemical reactions. We talk more of the principles of mass transfer and transport properties governing diffusion, fluid flow, gas-liquid, liquid-liquid and solid-liquid processes. Chemical engineers are being trained to consider processes almost entirely from the viewpoint of their scientific bases.

Versatility

While the chemical engineer has to be able to develop and design new process equipment, he is called on to play many other roles and his ability to do so is often astonishing. He is the most versatile technologist today.

Today's chemical engineer fills more different positions in society than any other professional man. He is found at all levels, not only in chemical industry but in other manufacturing fields, from Board Chairman down to process trainee; on faculties of course, including several college presidents; as vice-presidents of banks in charge of new investments and chemical departments. There are even a few ministers and MD's whose first degrees were in chemical engineering, and chemical engineers are found throughout Government and increasingly so.

Whatever advances have been made in chemical engineering, the hard core of fundamentals, and some practice in their application to man's needs, may account for this versatility. The increasing difficulty of covering all this satisfactorily in four years makes graduate training all the more desirable—and this too should be devoted to probing deeper into the basic sciences and engineering, and not into specialization such as textile technology, petroleum refining, or making new detergents.

Research & Development

It is perhaps the chemical engineer's propensity to get into research & development that finds him in later years in so many different lines, because he never knows where new developments may take him. He starts out in the petroleum industry, and he may find himself making automobile bodies or transparent film from hydrocarbon-based plastics! The chemical engineer, as much or more than any other technologist, is miscible in both solvents—the natural sciences, and their application in the arts which we call engineering.

The total U.S. expenditures for R&D have trebled in the past 8 years: 1950, $3 billion; 1958, $10 billion, of which Government now pays half. For the coming decade beginning next year, it is forecast that a total of $120 billion will be devoted to this country's R&D — substantially more than all that has been spent in the 183 years from 1776-1959.

What sort of new things are coming out of this? First of all, far more than we can imagine from the vantage point of today, which will seem surprisingly dark and poorly-informed when you people look back upon it in 1970. The material forms of the new technology will range from refrigerators with no moving parts (derived from solid-state physics), to controllable Space Devices and fuels.

What, you may ask, has the chemical engineer to do with all this? Basic to all these big and small developments are the technological contributions of synthetic polymers and of transistors, products of chemistry and engineering. Development and production of better polymers and plastics, and metals for transistors, electronic systems and missiles, are proving to be important fields for the chemical engineer.

Furthermore, the biggest bottleneck is in the development of engineering materials which will meet these new demands, especially for metals and alloys. There has been no break-through here comparable to the transistor in electronics, nylon in high polymers, or nuclear fission in energy creation. So we find the chemical engineer more and more in metallurgy, and the highest starting salaries paid to chemical engineers today in the metallurgical industries. So serious is the need for more versatile metals and alloys that scientists are urging the Government to establish a National Research institute for this sole purpose.

Electronic advances are hastening the automation of entire chemical plants. Even the tribulations of lengthy pilot plant developments are now being avoided by setting up all the variables, once determined, on a computer.

Challenges to the Chemical Engineer in the coming decade

If I were a young chemical engineer looking for the most interesting new field to tackle, what would I choose? This is a difficult question, because there are so many. My answer is personal opinion.

I would look first at man's greatest basic needs—Power, Water, and Food, all equally vital. What can the chemical engineer do about power? He has already had a major hand in the utilization of coal, oil and gas for power, as well as for a growing host of chemicals. With known limitations on these fuel reserves, he is working on their more efficient utilization, and must do much more, both in the processes for producing power, and in the processes which must consume it. One small but important example: the combustion of gasoline in the modern motor car permits about 7 percent on the average to leave the exhaust pipe unburned. In a large city, that disperses as much as 300,000 gallons of gasoline per day into the air, or a train of 30 large tank cars.

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continued on page 12

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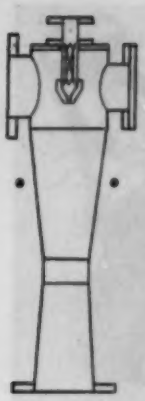

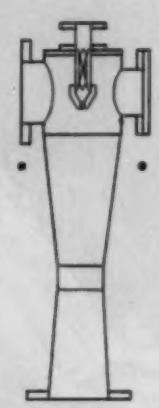

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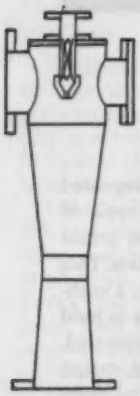

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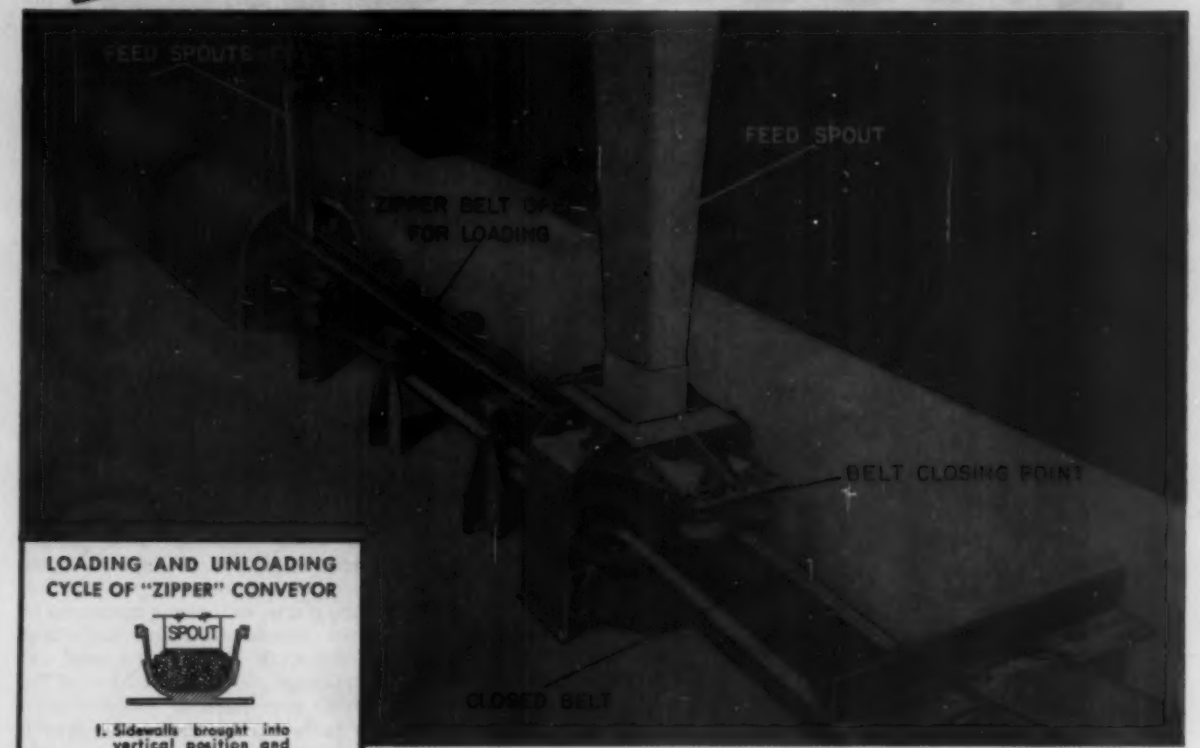

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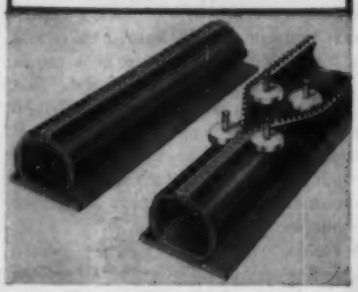

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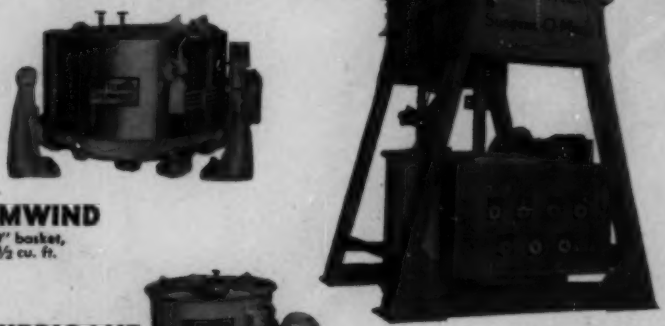

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from page 8

trical energy so that it can be used in a myriad of ways to reduce costs and give greater convenience.

Solar energy, so far developed as a supplement to conventional fuels in domestic heating, and then with the most marginal economics, is on the threshold of a break-through—to be applied first where fuel is scarce and therefore expensive.

The same areas which can profit most from solar energy are often those which have little or no fresh water. An economic process for the purification of saline water would be one of the greatest benefits that man could bring to his under-privileged and suffering brethren, and it's a natural for the chemical engineer! Pilot processes currently showing promise involve multiple-effect evaporation and vapor compression, freezing or dialysis, according to the environment. Costs are already coming down to where they are at least competitive or better in arid countries, which is to say they are still high by our standards.

That food supplies can become critical seems incredible in a country where we are still paying out our tax money for *not* raising hogs, wheat and other grains, and storing mountains of butter, cheese, dried milk and wheat until it spoils. But this is a local and short-range phenomenon. Most of the world's population is underfed even so. As the explosive population growth continues into the next century (only 40 years away), man will be forced to improve his production of food.

In perspective, the real role of the chemical engineer is to more efficiently use natural resources to satisfy in new and better ways the needs of a rapidly growing world, through conservation of energy, raw materials, food, water, and air; to make possible not only *continuation* of living conditions for our expanding population, but an extension of *improved* conditions throughout the world. We talk as if civilization's progress was measured in TV's and air conditioners, that chemical engineering has such trivial ends—these are but passing manifestations of the technological revolution which is how accelerating (less than a century old), which *must* accelerate if man is to survive.

(Banquet Address at 10th Annual Conclave, A.I.Ch.E. Student Chapters, Mid-Atlantic States Region, University of Virginia, Charlottesville, Va., April 18, 1959.)

MORE RADIATION PER DOLLAR

Atomic Energy of Canada Limited announces the availability, in quantity, of Cobalt 60 in the intermediate specific activity range of 5 to 40 curies per gram.

Many applications of gamma radiation do not require the more costly high specific activity needed for "point" sources or extremely "hot" sources.

IF YOUR COBALT 60 REQUIREMENTS CALL FOR INTERMEDIATE SPECIFIC ACTIVITY, YOU CAN NOW GET MORE RADIATION FOR EACH OF YOUR DOLLARS.

This Cobalt 60 can be packaged into capsules of almost any configuration. If one of our many standard "pencil" types does not meet your needs, we will make one that does. Welded stainless steel encapsulation is our forte.

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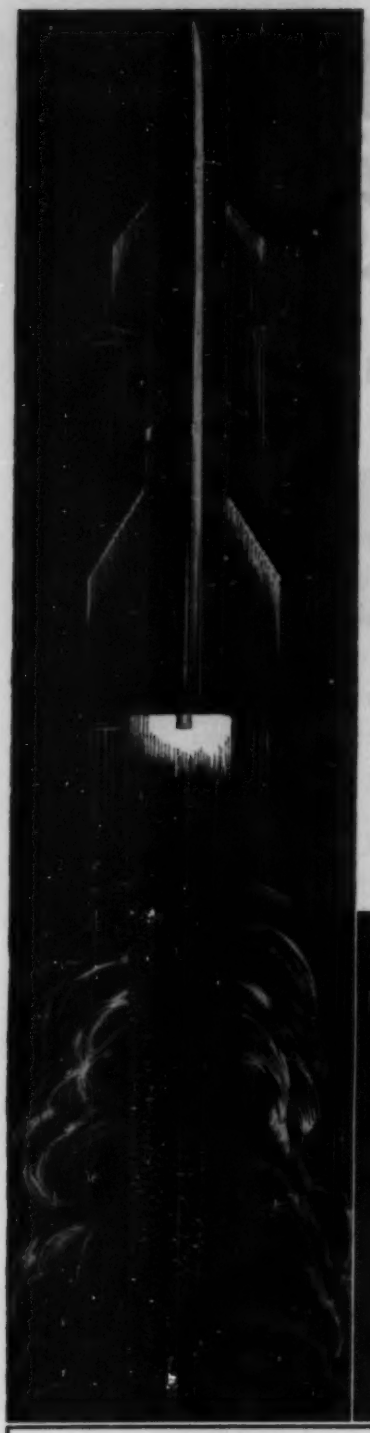


at Callery's new HiCal® plant

HEAVY-DUTY I-R COMPRESSORS

work full-time to produce

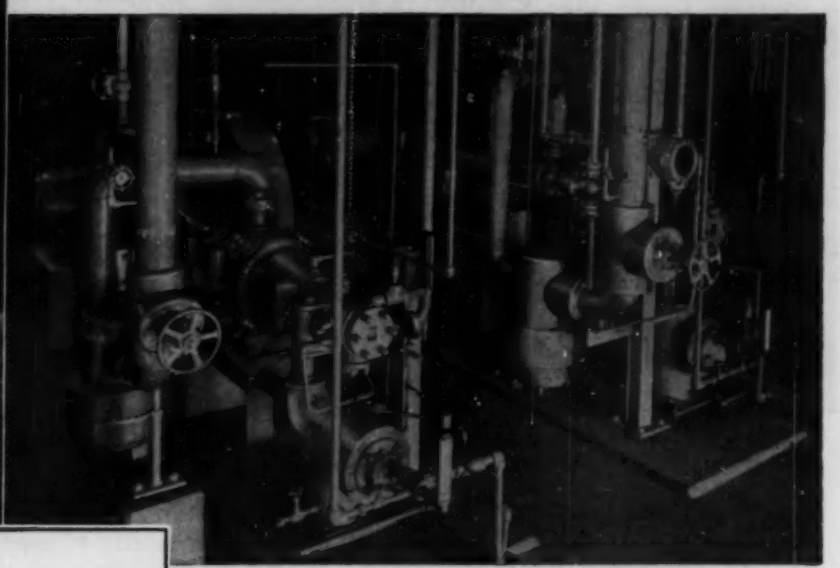
NEW HIGH-ENERGY FUEL

Recently the U.S. Navy and the Callery Chemical Company jointly dedicated their new HiCal plant in Muskogee, Oklahoma—America's first large-scale facility for the production of boron-based high-energy fuel. This new exotic fuel will power missiles, super aircraft, and possibly even man's first steps into space.

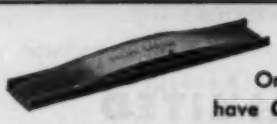
A large assortment of Ingersoll-Rand process compressors and pumps at Muskogee are working around the clock to maintain a continuous production schedule. One of the major processing units is the gas plant which produces hydrogen, carbon dioxide and nitrogen. Here a new-design Ingersoll-Rand ESH two-stage compressor handles carbon dioxide at 305 psig discharge, and another two-stage I-R unit compresses nitrogen to 500 psig. Two three-stage TVH's compress the hydrogen to 310 psig.

The Muskogee plant also includes 47 Ingersoll-Rand centrifugal pumps of various types and ratings.

Ingersoll-Rand's leadership in the manufacture of process equipment is the result of the world's most comprehensive compressor experience. Ingersoll-Rand now makes the widest range of compressors of all types, including reciprocating, centrifugal, axial-flow and jet units. Your Ingersoll-Rand representative will be happy to give you more information on gas or air compressors for any process requirement.



Ingersoll-Rand two-stage compressors at the new HiCal plant. At left, an ES nitrogen compressor; at right, compressing carbon dioxide, is an ESH unit of revolutionary new design.



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SCOPE

Engineering teaching salaries continue climb

Average professional income of engineering teachers in the U.S. rose from $8,862 in 1956 to $9,598 in 1958, an increase of $736, or 8.3%, according to results of a survey just completed by Engineers Joint Council under a grant from the National Science Foundation. Basic teaching salaries increased by an even larger amount, by $894, or 13.5%. The survey was based on approximately a 50% sampling of engineering teachers in the U.S. Median and mean salaries by rank are set forth in the accompanying table.

Median 1958 teaching salaries of engineering educators ranged from $4,950 for instructors to $12,500 for deans. For instructors, pay in publicly-supported institutions was slightly higher than in privately-supported ones. The trend was reversed, however, in the case of professors, with those employed in private schools outdistancing their counterparts in publicly-supported institutions. Department heads fared equally well in both categories.

Median total income from the practice of engineering in 1958 ranged from $5,900 for instructors to $14,572 for deans. Total income for all ranks, except lecturer, were higher in private than in public institutions. Differences for ranks from instructor through associate professor were small, but for professors, department heads, and deans, they are substantial. Conclusion—opportunity to augment teaching salaries by consulting and other outside professional activities remains better, at least for senior engineering faculty members, in private rather than in public schools.

Outside income down

The survey indicated an average decline in outside income from the practice of engineering of $157, or about 7%. This figure is composed of an average drop of $100 for educators in public institutions and an average drop of $311 for those in privately-supported schools. The decline in outside income is a result, in part at least, say the EJC surveyors, of the recession of 1957-58.

Median and mean salaries and income, by rank, 1958

PUBLIC

	Salaries		Income	
Rank	*Median*	*Mean*	*Median*	*Mean*
Instructor	$5,000	$5,043	$5,850	$5,954
Asst. Professor	6,043	6,175	7,313	7,564
Assoc. Professor	7,250	7,329	8,600	9,039
Professor	9,000	9,407	10,600	11,930
Lecturer	5,600	5,752	6,250	6,983
Department Head	10,000	10,575	12,000	12,715
Dean	12,000	12,672	14,000	15,075

PRIVATE

	Salaries		Income	
Rank	*Median*	*Mean*	*Median*	*Mean*
Instructor	$4,800	$4,849	$5,900	$5,959
Asst. Professor	6,100	6,280	7,900	8,305
Assoc. Professor	7,500	7,603	9,700	10,454
Professor	9,583	9,948	13,240	14,245
Lecturer	6,000	5,702	6,000	7,302
Department Head	10,000	10,582	13,215	14,328
Dean	13,250	13,705	17,275	17,478

ALL INSTITUTIONS

	Salaries		Income	
Rank	*Median*	*Mean*	*Median*	*Mean*
Instructor	$4,950	$5,009	$5,900	$5,955
Asst. Professor	6,060	6,209	7,500	7,801
Assoc. Professor	7,350	7,419	9,000	9,503
Professor	9,200	9,581	12,000	12,672
Lecturer	5,600	5,745	6,000	7,026
Department Head	10,000	10,577	12,450	13,236
Dean	12,500	13,059	14,572	15,978

First data on ethylene-propylene copolymer rubber

Outstanding resistance to heat, oxygen, ozone, and other aging and degrading agents is claimed for a new ethylene-propylene copolymer synthetic rubber now in semi-commercial production at Montecatini's Ferrara, Italy, plant. Wear properties are also said to be excellent.

The new synthetic, called C 23 rubber, is a high molecular weight copolymer of ethylene and propylene. Overall properties are very near those of natural rubber and, in many areas, are said to surpass those of conventional synthetics. Trump card in the new development is the cheapness of the starting materials; no actual cost figures are now available, however.

Rebound at 20°C is 75% with a minimum at minus 35°C. Its brittle point is well below natural rubber.

It is claimed that the new synthetic rubber can be easily mixed with normal fillers, and that it can be produced in various grades depending on application requirements. Auto tires made of the new material were recently exhibited at Milan, Italy, and are undergoing a series of road tests.

According to Montecatini, vulcanization formulations have been developed to permit processing of C 23 rubber with equipment and techniques in standard use by the industry. Mechanical properties of C 23 vulcanizates (Figure 1) lie in an intermediate range between those of natural rubber and butadiene-styrene copolymers. Specific gravity is low—0.85 to 0.86.

Figure 2 shows the resistance of the new C 23 rubber to aging, sunlight, ozone, and various chemical agents, compared to that of other commercial synthetic rubbers.

Mechanical properties	C 23	N.R.	S.B.R.
Tensile strength (ASTM D412-51T) lbs/sq.in.	3,600-4,000	4,100-4,400	3,700-3,900
Elongation at break (ΔL/L %)	450- 500	550- 600	400- 450
Stress at 300% elongation lbs/sq.in.	1,300-1,700	1,600-1,700	1,650-1,900
Tension set; test specimen stretched at 200% elongation, bar kept at said strain for one hour; measurement one minute after releasing in %	7-9	6	9
Hardness, Shore A.	60-65	65	67

Figure 1. Mechanical properties of C 23 vulcanizates as compared to those of natural rubbers and S.B.R. Reinforcement: 50 p.h.r. HAF

PROPERTIES	C 23	N.R.	S.B.R.	Neoprene	Nitrile	Butyl	Hypalon	Silicone
Resistance to:								
outdoor aging	5	3	3	5	3	5	5	5
sunlight	5	2	2	5	2	5	5	5
ozone	5	0	1	4	1	4	5	5
heat	4	1	2	3	3	3	4	5
flame	0	0	0	5	0	0	5	2
acids	5	3	3	4	3	4	5	3
alkalis	5	4	4	4	3	5	5	5
aliphatic solv.	1	1	1	4	5	2	4	1
aromatic solv.	0	0	0	1	3	2	1	0
chlorinated solv.	0	0	0	0	2	1	1	0
Lockheed hydraulic fluid	5	5	5	3	1	5	3	3

LEGEND

0	very poor	2	average	4	very good
1	poor	3	good	5	excellent

Figure 2. Other properties of C 23 (ethylene-propylene) vulcanizates as compared to commercial rubbers.

Israel nitric acid plant started up

A new nitric acid plant has been put on stream at Haifa, Israel, by Fertilizers & Chemicals, Ltd. Design and construction were by Societe Belge de l'Azote et des Produits Chemiques du Marly, Liege, Belgium.

Students advised to diversify

"Versatility is the keynote of success in a chemical engineering career," a gathering of student chemical engineers was told at a symposium on Careers in Chemical Engineering at the recent A.I.Ch.E. National Meeting in Kansas City.*

Advanced degrees in other subjects than engineering, even hobbies pursued as a matter of personal interest, can spell success or failure in an engineering career, emphasized members of the panel. It is almost impossible to predict what bit of knowledge will come in handy, or what any given student or young engineer will end up doing.

As a result, continued the panelists, no company recruiter can honestly tell a student what the future holds in store for him. One of the panelists, himself a recruiter for a large chemical company, said flatly that he would not hesitate to hire a young engineer who admitted that he did not know exactly what he wanted to do with the company. Students applying for jobs were also unanimously advised to disregard application blank demands calling for "salary expected."

Advanced degree no barrier

Panelists were in agreement that advanced degrees are not necessarily a barrier to advancement in the administrative world, that a Ph.D. does not automatically end up in some research post or other highly specialized but relatively poorly paid position. More and more companies, it was pointed out, particularly in the chemical field, are creating technical ladders alongside the traditional "line" administrative ladder. In such a set up, the scientist can hope for equal remuneration and prestige with line officers, without abandoning his field of special competence.

"Go to work for a company whose main interest is chemical engineering. Otherwise you will probably be the first to be dropped when the company is forced to retrench," said one of the panelists. This statement, however, met objections from other panelists, several of whom adduced instances in which a chemical engineer has risen to high administrative responsibility in a company whose main interest is in entirely different fields.

* *Panel members were: J. G. Knudson (moderator), Oregon State College; B. T. Mullaney, Crown Zellerbach Corp.; D. C. Holcomb, El Paso Natural Gas Co.; William Hesler, The Hesler Co.; James Warburton, California Research; Carl Spangler, C. W. Nofsinger Co.*

Congress moves to cut Euratom aid

A significant cut in U.S. aid to Euratom (six-nation European nuclear power group) has been proposed by the Joint Congressional Committee on Atomic Energy following reports that the Euratom program is falling seriously behind schedule.

Report from behind the Curtain

A rocket-propelled tunnel digger is said to be used in Russia to lay underground piping, reports the Office of Technical Services (Dept. of Commerce). According to the story, the front of the digger contains a pulverizing device which spouts flames from liquid fuel and compressed air . . . Also reported by OTS is a Russian plan for stepped up production of oxygen, large quantities of which will go into "a new, very promising process, the oxidative cracking of natural gas to produce acetylene."

Washington notes

AEC has been asked to provide a low-temperature nuclear reactor to be used as the heat source for the multi-stage flash distillation process selected as the basis for the second saline water demonstration conversion plant . . . Applications will be accepted through October 5, 1959, by the National Science Foundation under the Senior Postdoctoral and Science Faculty Fellowship programs. *J. L. Gillman, Jr.*

From here and there

Dow will build a polyethylene film plant near Fresno, California . . . Experiment Incorporated, high-energy fuel research organization will be acquired by Texaco . . . Callery Chemical has been awarded a contract by National Aeronautics and Space Administration for evaluation of a new classified rocket propellant . . . A $3 million high-level radiation laboratory at Oak Ridge will be designed by Vitro Engineering . . . Olin Mathieson plans to spend some $6 million for installation of chlorine and caustic soda facilities at its Niagara Falls, N. Y. plant.

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HUDSON Solo-aire units pictured above operate in a large Texas Gulf Coast Refinery, in which Solo-aires are used for a complete range of refinery services, transferring 300 million BTU's per hour directly to air.

Over-all economic comparisons of HUDSON Solo-aire cooling versus water cooling for new refining units almost invariably result in selection of Solo-aire units for much or all process cooling.

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Operating results of HUDSON Solo-aire units installed in oil, gas and chemical plants throughout the free world have led to continuing repeat installations.

For new process installations and for replacement of high maintenance water-cooled equipment, Solo-aires offer in most cases clear-cut advantages. Let HUDSON assist you in objective analyses of air versus water cooling.

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NEW HUDSON TUF-LITE FANS

After six years of development work and tests of trial field installations operating under wide ranges of conditions in cooling towers, finned tube coolers, and in highly corrosive chemical plant ventilating service, Hudson presents a new product—the TUF-LITE fan. The blades, cast in one seamless piece of fiber glass reinforced synthetic resin, are hollow, light and tough. TUF-LITE fans afford the following advantages over any other available type of fan:

SAFE: TUF-LITE blades being lightweight (about ¼ the weight of other blades with comparable capacity) and infrangible, eliminate the hazards to personnel and equipment existent through accidental throwing or disintegration of heavy metal, wood, or laminated blades while in service.

EFFICIENT: More air is moved at less horsepower because weight and finishing operations do not impose limitations on selections of best aerodynamic design; therefore nearly ideal airfoil cross sections, commercially attainable only in TUF-LITE blades, can be used. Blades will not sag or distort, and surfaces remain permanently smooth.

LOW MAINTENANCE: TUF-LITE blades are unaffected by corrosive, abrasive or impingement effects of hot saturated air, sand, rain, or hail, and have superior deterioration resistance to practically all corrosive vapors or liquids. Blade materials contain color pigment; no painting is necessary. Light weight reduces stress and maintenance on bearings, gears, drive shafts, and supports.

QUIET: The permanently smooth surfaces, very light weight, sustained perfect balance, and advanced aerodynamic design minimize noise.

EASE IN INSTALLATION: Light weight of blades and ingenious design of hub and blade coupling allows attachment of blades by one man using only small wrench. Coupling design assures uniformity of pitch of all blades, and as blades of same size are identical and interchangeable, perfect fan balance is preassured.

In replacement of present fans or in installations on new cooling equipment of any manufacture TAKE ADVANTAGE OF THE OUTSTANDING SUPERIORITY OF HUDSON TUF-LITE FANS.

Bulletin on TUF-LITE FANS
Available upon Request

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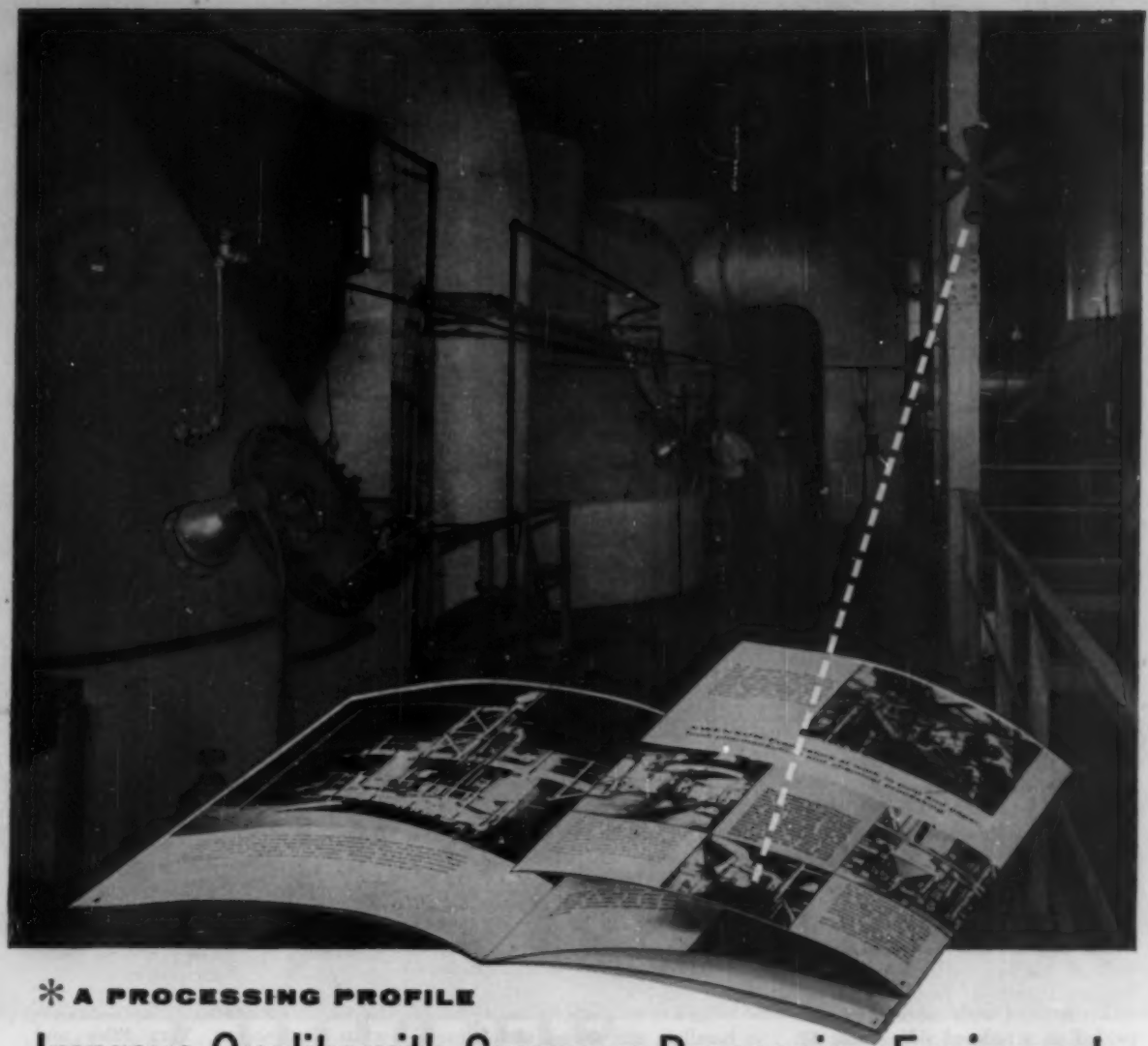

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The hazards of nitroparaffins. This crater is the aftermath of the explosion of a nitromethane tank on a railroad siding at Mt. Pulaski, Illinois.

Safe Handling & Storage of nitroparaffins

NITROPARAFFINS AND THEIR HAZARDS, Research Report No. 12, National Board of Fire Underwriters, 85 John St., New York 38, N. Y. 66 pp. *Available on request.*

At 9:30 Wednesday morning, January 22, 1958, a tank car of nitromethane blew up in a railroad switching yard at Niagara Falls, N.Y. At 4:00 Sunday afternoon, June 1st, another tank car filled with nitromethane exploded on a railroad siding near Mt. Pulaski, Ill. What caused these explosions? How can others be prevented?

The National Board of Fire Underwriters has issued a booklet which goes far into both the mechanism and initiation of nitromethane explosions, as well as common sense ways to prevent recurrences.

Reported, for instance, is a series of tests conducted at an isolated spot in Utah for Commercial Solvents Corp., the manufacturer of nitroparaffins. 50-calibre ammunition fired into ordinary containers filled with nitromethane did not blow up, yet if heavy-walled containers were used, fragmentation occurred which would cause detonation. A 6x6 piece of ¾-in. steel plate projected with tremendous force into a drum of nitromethane caused it to explode. Full drums were dropped 50-ft., and finally from a low flying airplane without detonation. Sudden impact of 2,000 lb./sq.in. air causes explosion—doubtless combining both temperature and pressure effects. Pipeline hammer of nitromethane flowing into closed end pipes can be dangerous. In general, sensitized compounds (either alkaline or highly oxygenated materials—esters excepted) greatly lower nitromethane's susceptibility to shock detonation.

What's to be done, to assure safety in handling and storing of this useful family of solvents and intermediates? Temporarily, shipments by tank cars and tank trucks have been suspended. Drums can be shipped, containing an inert gas in the void space for "blanketing." Experience over a period of about 10 yrs. with drum shipments has been satisfactory, without incident. The presumption is that contaminants in reusable containers such as tank cars and trucks having previously held other materials, act as the nitromethane-sensitizing culprits.

The NBFU makes a number of precautionary recommendations, such as the providing of a "suitably isolated outdoor storage facility . . ." using "the drums in which it is received, or an underground tank with suitable corrosion protection and with a minimum of 2 ft. of earth over the tank . . . ."

Mixtures with heavy metal oxides, dry or highly concentrated strong alkalies, easily oxidizable substances at elevated temperatures, etc. are to be avoided. Excessive temperature, pressure, shock, contamination, etc., are likewise to be prevented.

This comprehensive report contains much quantitative data, test and apparatus descriptions, and other details. A design for an expansion tube which prevents the propagation of a detonation in a pipe line, is shown in a construction drawing.

Here is a booklet describing an exemplary approach to the evaluation and solution of problems associated with handling and use of hazardous and extra-hazardous chemicals.

KINETIC THEORY OF GASES, R. D. Present, McGraw-Hill Book Company, New York, N.Y. (1958), 280p. $7.75.

An introduction, covering distribution functions and the perfect gas law; mean-free-path methods and transport phenomena; the Maxwell-Boltzmann distribution law; imperfect gases and intermolecular forces; thermal and mutual diffusion; collision dynamics, cross-sections and chemical kinetics; brownian motion and density fluctuations.

VINYL RESINS, W. Mayo Smith, Reinhold Publishing Co, New York, N.Y. (1958), 282p. $5.75.

Provides information on types, properties, chemistry, manufacture and fabrication of vinyl resins. Polymerization systems for vinyl chloride is detailed, as well as polyvinyl chloride "pearls" and Delrin resin.

LINEAR PROGRAMMING AND ASSOCIATED TECHNIQUES, Vera Riley and Saul I. Gass, John Hopkins University Press, Baltimore, Md., (1958), 613p. $6.00.

A bibliography containing over 1,000 items. Emphasis is on production scheduling and inventory control. Game theory and linear inequalities are touched upon.

NUCLEAR ROCKET PROPULSION, R. W. Bussard and R. D. deLauer, McGraw-Hill Book Company, Inc., New York, N.Y. (1958), 370p. $10.00.

NUCLEAR REACTOR METALLURGY, Walter D. Wilkinson and William F. Murphy, D. Van Nostrand Company, Inc., Princeton, N.J. (1958), 382p. $5.60.

MACHINERY AND EQUIPMENT FOR RUBBER AND PLASTICS: VOLUME II: SUPPLEMENTARY MACHINERY AND EQUIPMENT. Compiled by Robert G. Seaman, Rubber World, New York, N.Y. (1958), 714p. $15.00.

PHTHALICS

AN EXCLUSIVE FLUID BED PROCESS... ENGINEERING, CONSTRUCTION AND OPERATING EXPERIENCE... ALL AVAILABLE FROM BADGER

Badger is now sub-licensing the fluid bed catalytic process originally developed by The Sherwin-Williams Company for its own successful phthalic anhydride plant.

Numerous refinements have been contributed to the process by Badger. These include new purification techniques, better reactor design (including more efficient heat removal), improved condensing and recovery sections for effluent gases. The process has these advantages over conventional fixed bed methods: *Low capital and operating costs* — smaller, simpler equipment saves 20% or more on plant investment, cuts utility and operating labor costs up to 30%. *Better yield* — process converts 5-10% more of feed naphthalene to phthalic anhydride. *Flexibility* — throughput may be varied over a wide range; process is easy to control. *Highest product quality* — heat color stability is high due to fewer impurities. *Safety* — fluid bed reactor virtually eliminates possibility of explosion.

With the process Badger offers unmatched engineering, construction and operating experience . . . gained in working with Sherwin-Williams . . . from the design and engineering of two current phthalic anhydride projects (see right)... through a broad background in fluid bed processes in general. It's as simple as this: when you are considering new phthalic anhydride facilities, come to Badger for the answers. Write or call Badger Manufacturing Company, 363 Third Street, Cambridge 42, Massachusetts.

Two major phthalic anhydride projects current at Badger

At Elizabeth, N. J., Badger is constructing a 30 million lb/yr phthalic anhydride plant for Reichhold Chemicals, Inc. When completed in late 1959, it will produce about 16% of U. S. production of phthalic anhydride made from naphthalene.

Another fluid bed plant, similar in design and capacity to RCI's, is being handled for ACNA (a subsidiary of the Montecatini group) in Milan, Italy. This plant is also scheduled to go on-stream in 1959.

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ENGINEERS • CONSTRUCTORS

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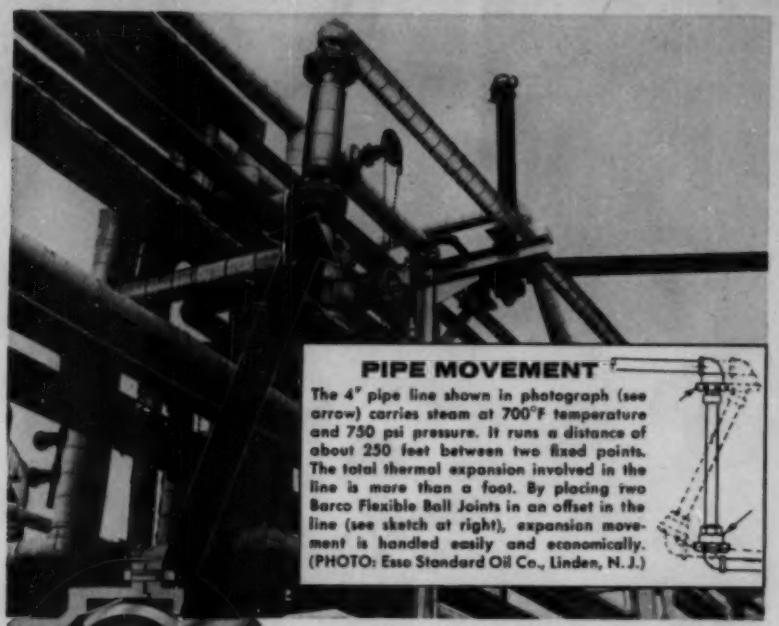
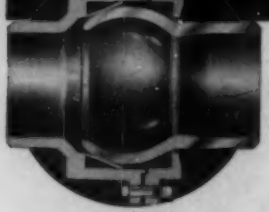


PIPE MOVEMENT

The 4" pipe line shown in photograph (see arrow) carries steam at 700°F temperature and 750 psi pressure. It runs a distance of about 250 feet between two fixed points. The total thermal expansion involved in the line is more than a foot. By placing two Barco Flexible Ball Joints in an offset in the line (see sketch at right), expansion movement is handled easily and economically. (PHOTO: Esso Standard Oil Co., Linden, N. J.)



BARCO HT HIGH TEMP. Flexible BALL JOINTS

SAVE VALUABLE SPACE

ADVANTAGES:

SAVE SPACE—Barco Ball Joints are used to perform functions similar to U-bends or pipe loops—But with much less space required and often LOWER COST.

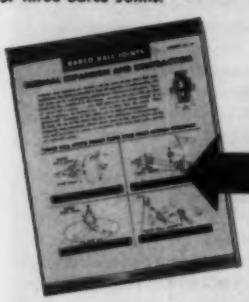
NO PRESSURE THRUST—Expensive anchoring or bracing not required to hold piping in place or in line.

HIGH TEMPERATURE, PRESSURE—Wide choice of materials in new Barco HT Joints.

SIMPLE—Easy to solve virtually any problem with aid of two or three Barco Joints.

The Barco HT (High Temperature) Flexible Ball Joint is a new development. It is *the key* to solving many PIPE EXPANSION PROBLEMS where high temperatures and pressures are encountered. The outer sealing gasket is a special, high temperature ring. The inner take up ring is self-adjusting to thermal expansion and maintains tight sealing action without building up high resistance (friction) to turning or angular flexing. HT joints can be supplied in sizes from 1" to 12", angle or straight, and can be fabricated from materials to withstand as much as 1000°F, 1200°F, or even 1400°F, under certain conditions.

Local Barco Field Engineers will be glad to give you full information and recommendations. Call or write today.



Send for this BULLETIN 31

"How to Solve Piping Flexibility Problems". Complete with piping layout drawings and illustrations. Shows how to cut costs, save time, and do a better job!

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about our authors

(l. to r.) Authors Smith, Todd, Gillespie

R. B. Smith (*Kinetic Analysis of Naphtha Reforming with Platinum Catalyst*) has been engaged in process design work with Sinclair Research Laboratories for the past thirty years. Now director of the Design Division at Harvey, Illinois, he participated in the design of most of the units now in operation at the company's six refineries. Smith is author of a number of papers, and holds several patents.

Jerry F. Todd (*Field Performance Testing of Air-cooled Heat Transfer Equipment*) has served Magnolia Petroleum Co. since 1950 in several engineering capacities. He is currently in gasoline plant mechanical maintenance.

Thomas G. Gillespie, Jr. (*Legal Aspects of Foreign Licensing*) was just recently made vice president of Scientific Design Co. after several years with the firm. Much of the company's work is abroad, engineering and building organic and petrochemical plants. Gillespie is in charge of legal and contract matters, as well as other development activities. He has an LLB from Indiana U. as well as his degree in Chemical Engineering.

Willard C. Asbury (*Petroleum Industry—Progress through Licensing*), an Esso man since 1927, helped organize the company's laboratories in Baton Rouge, La. Several years of overseas assignments for the company followed. In 1947, he was named vice president and member of the board of directors of Esso Research and Engineering, a position he still holds. Asbury's current major responsibilities for the company are patent, legal and information activities. He has written numerous technical papers on patent activities, and has patents in the field of oil hydrogenation. Asbury is vice chairman of the advisory council of the Patent Trademark and Copyright Foundation, an organization established to promote research and education regarding laws in these fields.

continued on page 26

For more information, turn to Data Service card, circle No. 42

For more information, circle No. 35

ECO ENGINEERING NEWS

the big name in small pumps for the process industries

From the Engineer's Notebook

Watch for a new and revolutionary Eco valve which utilizes atmospheric pressure to activate and dispense exact small amounts of highly viscous, heat-sensitive fluids—glycerine, biologicals and other pharmaceuticals, etc. Handles them at room temperature without contamination or frictional heat which might cause discoloration or affect purity.

Lever operated, it meters volume dispensed with accuracy greater than ±1 per cent. Now being secretly tested by key plants. Public announcement soon.

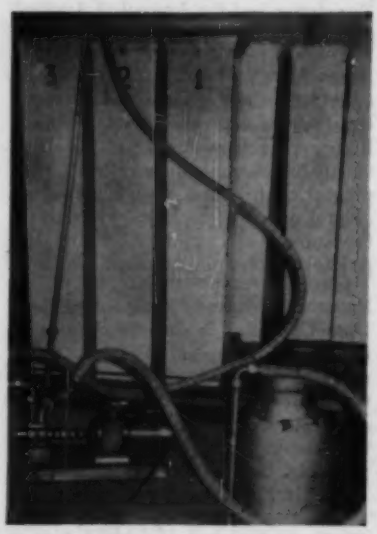
Coffee Break

Coffee is not a chemical per se, but chemists drink coffee—and like its sensitive flavor, uncontaminated.

Folger's Coffee, Houston, Tex. had problems in pumping concentrated coffee extract. Number 1—prevent contamination of product flavor and quality. Number 2—overcome pressure differential in pumping through filter to maintain same filtration rate throughout run. Number 3—lift extract out of tank without need for pump priming.

Eco ALL-CHEM* stainless steel and TEFLON† pumps are answering all requirements at lowest cost.

Eco pumps of this same design were originally proved for such service at the U. S. Dept. of Agriculture, Eastern Research Laboratories, Wyndmoor, Pa., which undoubtedly suggested their use to many coffee processors throughout the industry.



Eco ALL-CHEM Pump with Graham Varispeed Transmission at Folger Coffee.

Paper Mills Pick Eco Pumps for Chlorine Dioxide Bleach

3000 hours without a rest—24 hours a day. Tough pumping job, but typical, at West Virginia Pulp and Paper Company's Luke, Maryland Plant, where three Hastelloy* C GEARCHEM* pumps equipped with TEFLON Gears, bearings and packing have been in operation pumping chlorine dioxide bleach and water at about 120° F and 60 psi.

Equivalent to nearly a year and a half of service at the usual 40 hour per week level, these pumps have used only two repair kits to keep them in continuous operation.

These pumps are used in constant flow metering of relatively small quantities (1 to 5 gal. per min.) to maintain bleach at predetermined strength and hence to control uniform color of kraft papers.

An added advantage from their use is found in the fact that these pumps eliminate air entrainment and hence minimize corrosion, protecting allied piping and equipment.

Successful operation at Luke has prompted a reorder of this same design for the company's other Plants.

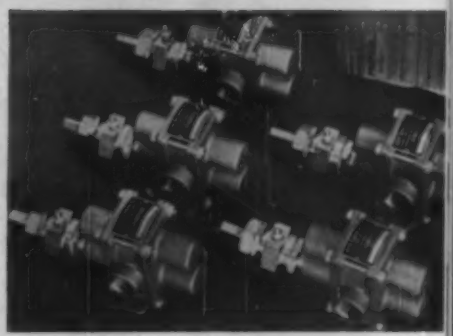
High Strength Phenolic Gears Withstand Vapor-Lock Shock-Loads at U.S. Rubber's Naugatuck Chem. Div.

The Pumping Service: handling butadiene and styrene monomers with 100 psi discharge pressures.

The Problem: the system created vapor-locks and shock-loads which shattered pump mechanisms.

The Solution: Eco Hastelloy C GEARCHEM Pumps with Phenolic Gears. These gears, which are non-affected by petroleum derivatives, are operating in a temperature range from ambient to 120° F. They are maintaining pressures and absorb back pressure shocks without suffering mechanically in any way, whatsoever.

QED: Eco's mass-produced, standard stock pumps may be engineered to the requirements of each individual job simply by varying the selection of the precision-made, interchangeable parts, available in the widest variety of metals and non-metallics.



Five More Eco Pumps for Selective Ore Preparation

A leading Chicago metallurgical corporation (name withheld by request), has been using several Eco GEARCHEM Pumps for a particularly difficult pumping job—70 per cent Hydrofluoric Acid and Methyl Isobutyl Ketone plus Sulphuric Acid—in chemical extraction refining of rare metal concentrates.

These pumps are pH controlled to maintain desired range of concentrations in continuous make-up.

The pumps—400 Series, 10 gpm GEARCHEM design—are constructed of Hastelloy C with TEFLON Gears, Bearings and packings and grease sealed lantern ring stuffing boxes. Suction lift required for the highly fugitive solvent is 9 feet; for the acid 18 feet. Required discharge pressure is 50 psi.

This application has been so successful that the customer has reordered five more identical Eco pumps for a new installation in their Oklahoma plant.

Editor's Note:

This page is page 1 of a regular publication, issued by Eco Engineering Company, reporting "What's New" in small pumps and allied equipment, and their successful application in industry. If you are not on our mailing list to receive this Eco publication, write on your company letterhead. We will be glad to "welcome you aboard."

ECO Products for Handling Corrosive and Hazardous Processing Fluids

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MINILAB Rotary Pumps
GEARCHEM Gear Pumps
CENTRI-CHEM Centrifugal Pumps
PUMPMOBILE Portable Pumping Units
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Ask for literature on any or all of these ECO Products

*ECO Trademarks, †du Pont Trademark. *Union Carbide Trademark.

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High-impact, rubber-plastic, most economical for average chemicals. ½ to 6". Screw or solvent welded fittings. Valves ½ to 2". NSF-approved. *Bul. 80A.*

An easier way to put corrosion under your thumb

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Choice of Riviclor PVC, Ace-lite rubber-plastic, Ace polyethylene or Ace Saran to match *any* plastic pipe. Sizes ½ to 2". Also larger plastic-lined valves.

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ACE processing equipment of rubber and plastics

AMERICAN HARD RUBBER COMPANY
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about our authors

from page 24

Authors Kern (left), Marquardt

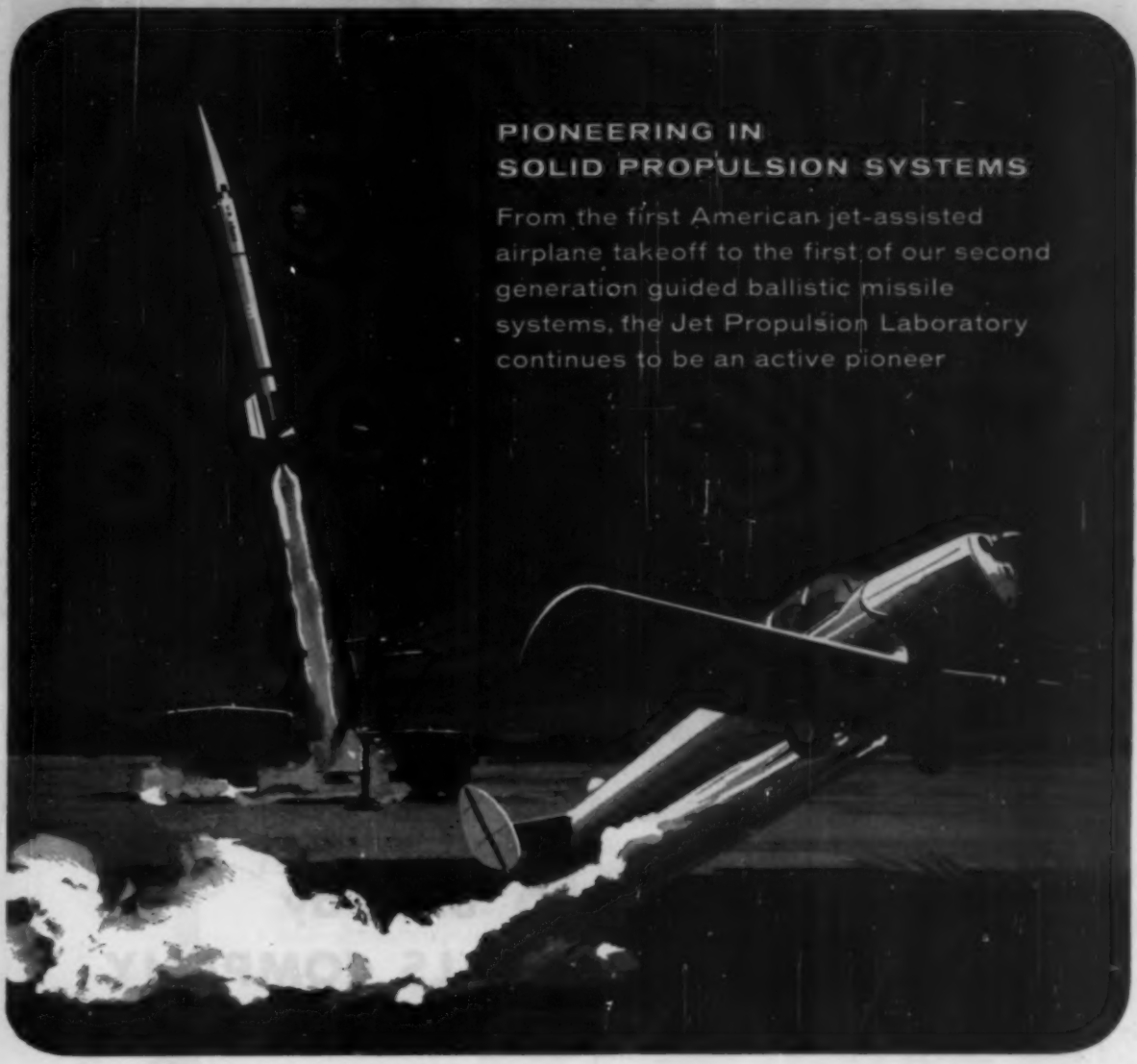
Donald Q. Kern (*Surface Fouling-How to Calculate Limits*) sincerely believes that all our thermal process plants are designed upon traditional fallacies and should be torn down or revamped. His paper is intended to point out what he considers the right direction. Kern was employed in managerial capacities in thermal process design and equipment engineering for fifteen years. He now heads his own organization, D. Q. Kern Associates, in Cleveland, and is engaged in mathematical development and the engineering of thermal processes and components. Kern is also an educator, lecturing at present in the graduate school of Case Institute of Technology. Previously, he conducted graduate courses in thermodynamics and heat transfer at Brooklyn Polytech. **Ralph E. Seaton,** co-author of the paper, is with the Wolverine Tube Division of Calumet and Hecla in Michigan.

Donald W. Marquardt (*Solution of Nonlinear Chemical Engineering Models*) has been with Du Pont in Wilmington since 1953. His present title is research project engineer. His interests are many: nonlinear statistics, numerical methods, functional approximation, time series analysis and mathematical programming. Marquardt has published articles in IBM Technical Newsletter and the Journal of Applied Physics.

James W. Westwater (*High Speed Photography for Chemical Engineering Phenomena*) is in the Chemical Engineering Department at the University of Illinois. In addition to his present contribution, he has published several papers in technical journals on the subject of heat transfer and the physical properties of plastics.

Rauer H. Meyer (*Technical Export Data Controls*) is director, Materials Division, Bureau of Foreign Commerce under the U. S. Department of Commerce, and has responsibility for control over exports of ferrous and non-ferrous metals, and petroleum products. He has been in government service for eighteen years, and with the Commerce Department since 1946.

NOTABLE ACHIEVEMENTS AT JPL...


PIONEERING IN
SOLID PROPULSION SYSTEMS
From the first American jet-assisted airplane takeoff to the first of our second generation guided ballistic missile systems, the Jet Propulsion Laboratory continues to be an active pioneer

In August 1941, America's first jet-assisted airplane takeoff was accomplished with an Ercoupe monoplane, using JPL developed solid propellant rockets. Scientists at JPL shortly discovered that a powdered perchlorate oxidizer, mixed with a liquefied plastic fuel binder, could be cast directly in plastic-lined light-weight motor cases. Thus a safe and cheap method was now available for preparing large internal-burning composite propellant charges. This basic process became the foundation for the modern solid propellant industry.

In 1954, U. S. Army Ordnance requested JPL to develop a compact, rugged long-range guided missile weapon system that could be transported, aimed and fired as simply as a cannon. Within five years, JPL perfected the **Sergeant**, the first of America's second-generation guided ballistic missiles. In January 1958, clusters of small-scale **Sergeants** helped launch America's first earth satellite, the JPL built **Explorer**, which provided vital space environment information.

Now under the direction of the National Aeronautics and Space Administration, the experienced JPL research and development team continues to apply solid propellant vehicles for space exploration.

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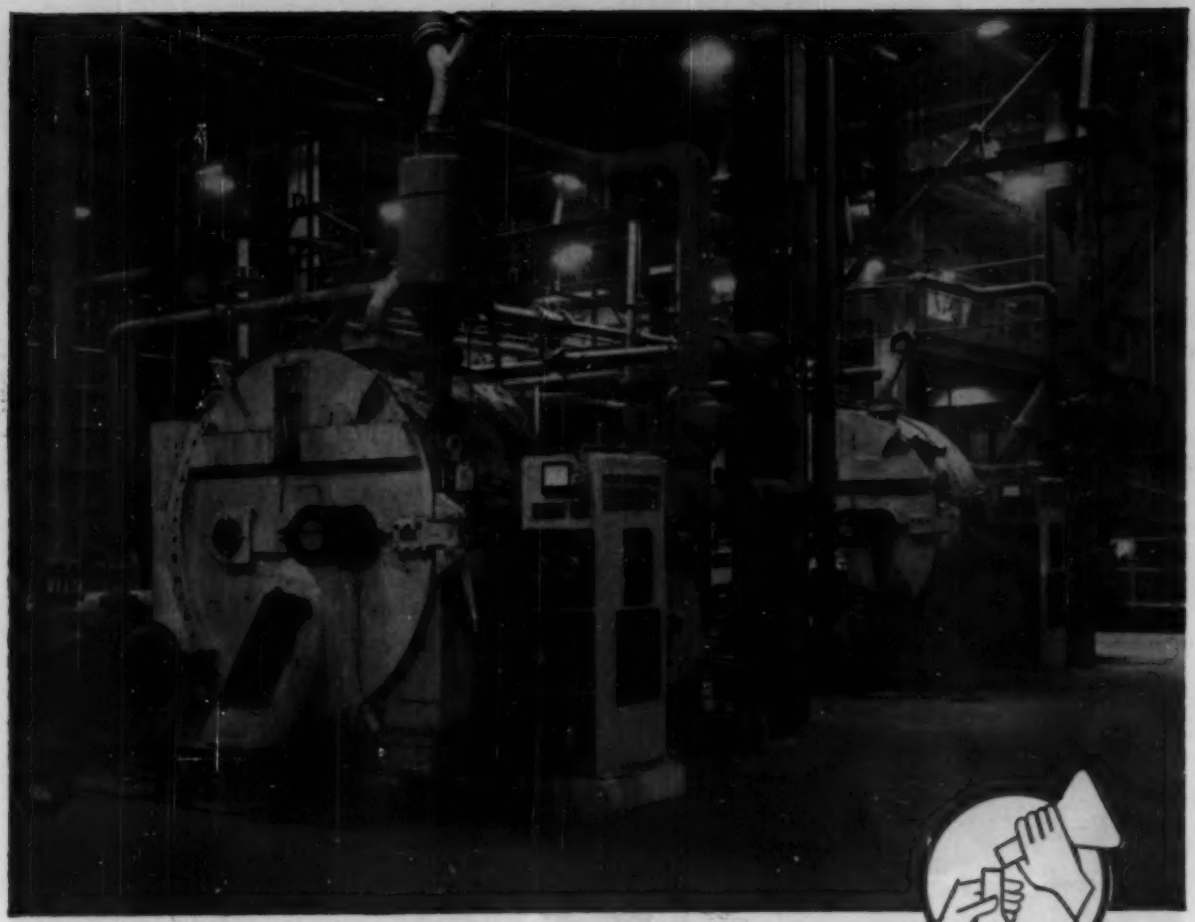

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Although a metal, titanium is produced by a chemical process. Metal in the form of ore is converted to titanium tetrachloride, which is purified and then reduced to metallic sponge by sodium. In order to separate the brine from the titanium sponge, Union Carbide Metals Company, Division of Union Carbide Corporation, New York, utilizes Baker Perkins 66" diameter type HS Universal Centrifugals. It's a tough application, but the B-P Type HS has proven itself efficient and dependable. These same machines are adaptable to a wide range of filterable fine solid-liquid slurries. Baker Perkins also manufactures type S Continuous Centrifugals which are used extensively for the separation of filterable coarse solid-liquid slurries.

Since centrifugation is such an important process in the chemical industry, and, since there are so many types of slurries that must be separated, Baker Perkins engineers give special design consideration to each specific problem. No matter what factors are involved in each application, our engineers can make recommendations on the proper centrifugal machinery.

Send for your copy of Catalog CS-59 for complete information on size, type and capacities of Baker Perkins "Tor Mear" Centrifugals.

BAKER PERKINS INC. CHEMICAL MACHINERY DIVISION SAGINAW, MICHIGAN

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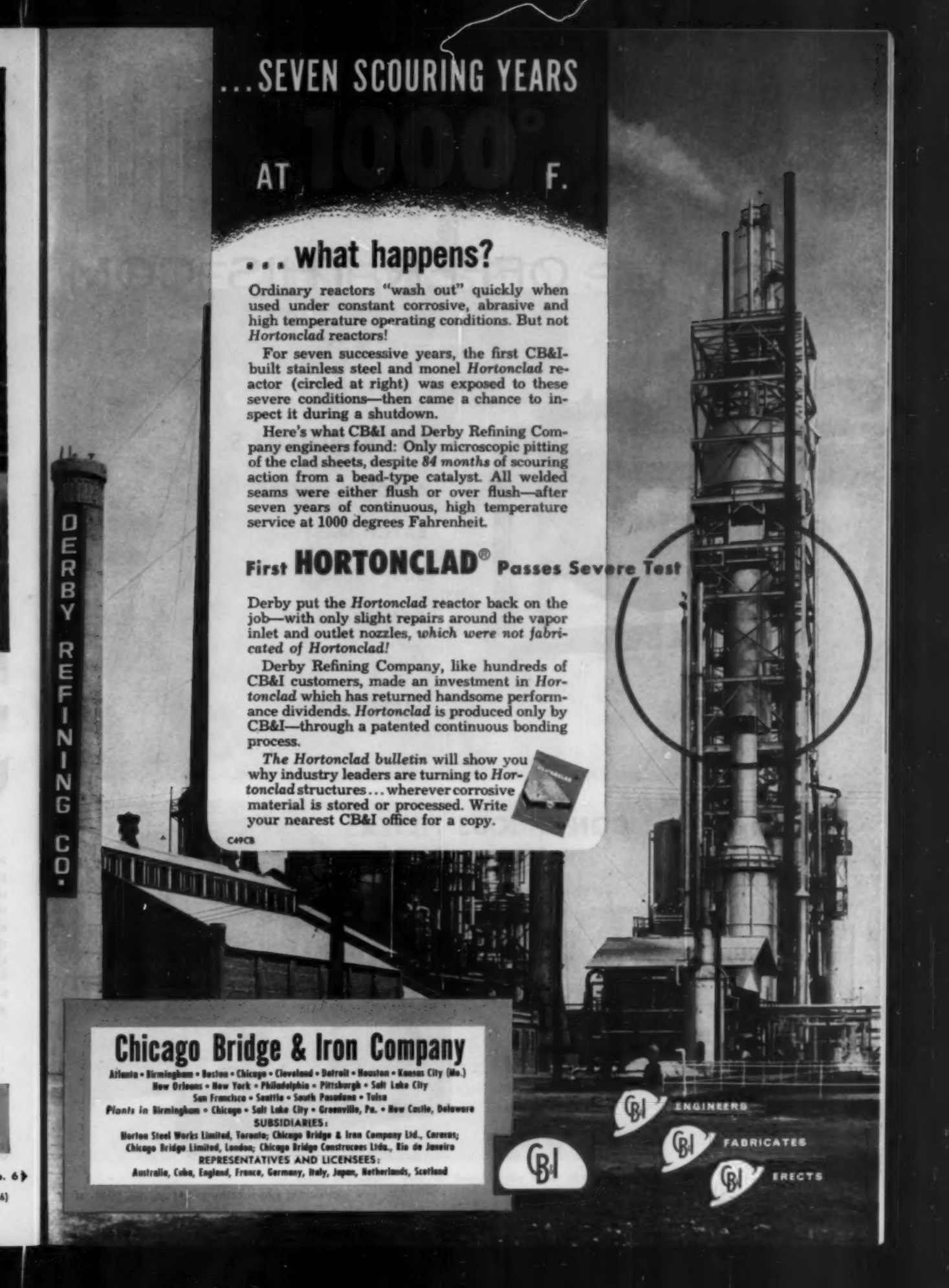
For more information, circle No. 6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For seven successive years, the first CB&I-built stainless steel and monel *Hortonclad* reactor (circled at right) was exposed to these severe conditions—then came a chance to inspect it during a shutdown.
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The Hortonclad bulletin will show you why industry leaders are turning to *Hortonclad* structures... wherever corrosive material is stored or processed. Write your nearest CB&I office for a copy.
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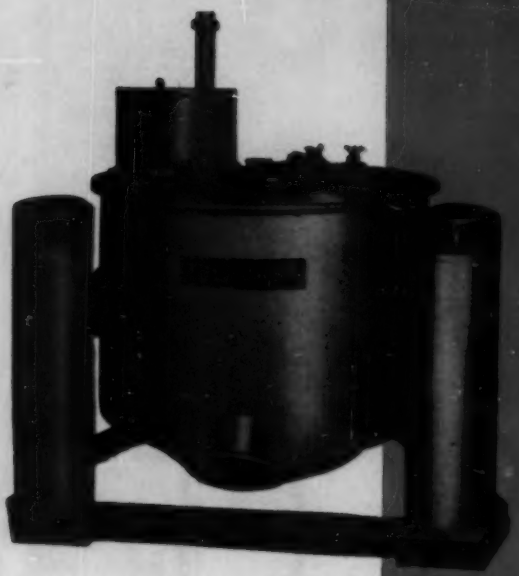

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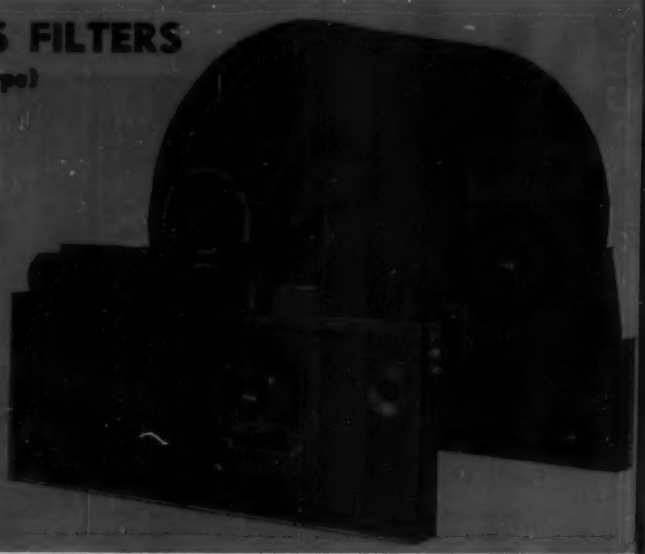

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CEP trends

Really out of the recession?

"As far as business statistics go, it would appear that the recession is over, and we are advancing to new peaks of prosperity. However, I am unable to agree entirely with this conclusion, because economic statistics frequently conceal some very serious problems," began Union Oil's board chairman Reese H. Taylor, commenting on the nation's economy at his firm's annual meeting.

"Some of this spring's apparent progress is the result of a boom in the steel industry," continued Taylor. "There is a possibility of a steel strike of long duration starting this summer. Forward buying in anticipation of this strike has driven steel production to all-time records in recent weeks. These production rates appear to be beyond those justified by the over-all level of the economy. As a result, these rates probably will decline in the second half, whether or not there is a strike."

Although price levels have been fairly steady in recent months, Taylor believes costs in most industries are still rising. Growth in Government spending, and featherbedding by labor along with increases in wages and other benefits, are held to be inflationary, even though accompanied by some deflationary prices resulting from increased competition both here and abroad.

That American products are losing world markets is of particular concern to Taylor, who cites that steel exports from the U.S. declined 40 percent. He cites his own company's experience as a first-hand example of what is happening. Union Oil "can purchase from either Japan or Europe pipe delivered in the Argentine for $23 a ton less than the same pipe delivered at the mill in Pittsburgh." High labor costs and confiscatory taxes are responsible for pushing American costs out of competition, according to Taylor, who feels that "adjustments, difficult to accomplish, will be necessary if we are to be competitive in world markets." Automation is indicated by Taylor as a solution which could be rapidly adopted by industries throughout the country.

Western Europe is now experiencing a much more rapid growth in chemical production than is the case in the United States, according to data issued by the OEEC*, and reported by Smith, Barney & Co. For the first half of 1958, OEEC chemical production increased 6 percent, while U.S. production for the same period decreased 3 percent. Petrochemicals production growth has been extremely rapid; 1958 was up 38 percent over 1957, which zoomed 37 percent over 1956. The six Euromart countries (France, Italy, Germany, the Netherlands, Belgium, and Luxembourg) sold in 1957 $10 billion in chemical products, as compared with U.S. sales of $23.4 billion for the same year.

The skillful timing of credit restraint and credit ease by the Federal Reserve System is "our strongest weapon against recession" or inflationary boom—so states the Chamber of Commerce of the United States in a new publication "Economic Lessons of Postwar Recessions." Our ability to foresee trouble, to determine the severity of a recession once it has begun or to recognize the beginnings of recover, leaves much to be desired, according to this commentary.

Sharp gains in earnings by many chemical companies as reported in reports for the first quarter of 1959 bring welcome news. Of twelve chemical companies' returns analyzed by CEP, an average increase in sales of 19 percent was accompanied by an average increase in earnings of a whopping 44 percent. Nalco, Spencer, and Witco showed sales gains of more than 30 percent, while Commercial Solvents and U.S. Borax & Chemicals both exceeded 80 percent gains in net earnings. The actual figures are as follows:

	sales	earnings
Atlas Powder	+ 5%	+30%
Commercial Solv	19	86
Foote Mineral	26	42
Heyden Newport	25	58
Merck	12	20
Nalco Chemical	38	54
Olin-Mathieson Chem	25	43
Procter & Gamble	–	11
Spencer Chemical	32	39
Union Oil	–	13
U.S. Borax & Chem	12	108
Witco Chemical	34	26

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7 Sizes—up to 600 gal. per min. • Total Dynamic Head—up to 275 ft.
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AVAILABILITY! Orders received before 11 a.m., E.S.T., shipped same day. Complete pumps, sub-assemblies and parts always available.

RELIABILITY! Wide versatility of application and full interchangeability of pumps and parts combine to make Dean Brothers Type "GS" pumps the universal plant standard.

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opinion and comment

Recognition for the engineer

One manifestation of this age of communication, we suspect, is that the opinions of engineers ten or more years out of school are beginning to be communicated right down the line to the high school graduate. So widespread is this transmittal that industry would do well to survey its treatment of engineers to see whether or not they are given the opportunity to be the valuable men in use that they seemed to be in promise. We refer of course to the drop in engineering enrollments. Have students heard that an engineer, while avidly sought on graduation, is not so highly regarded after ten years of service as is a salesman, a comptroller, a lawyer?

A recent survey of 1948 graduates in more than two hundred business and industrial firms made by Frank Endicott, Director of Placement at Northwestern University, notes that, although starting salaries are generally higher for engineers, at the end of ten years the average accountant and the average salesman earn more than does the engineer. Just recently, too, a study team back from the USSR reported in the May, 1959, issue of the *Journal of Engineering Education* what had been learned about the way the USSR encourages engineers. This team was headed by Frederick C. Lindvall and had as one of its members a noted chemical engineer, Ralph A. Morgen. "The motivation of the student for superior accomplishment," noted the report, "is the most outstanding feature of engineering education in the USSR. The motivation is based on *prestige*, *privilege*, *financial reward*, and an obligation to serve the State."

In a democracy privilege is not an acknowledged goal, and by *service to the State* we probably understand something a little different from the Soviet conception, but if engineering talent in the United States is to be kept at engineering tasks, we shall have to recognize its worth. Industry in the United States pays for what it needs. Is it true, therefore, to state (1) that the United States needs young engineers more than it needs young accountants and young salesmen, (2) that there is less need for engineers with several years of experience than there is for experienced salesmen, accountants, and administrators? Frankly, these conclusions don't make sense.

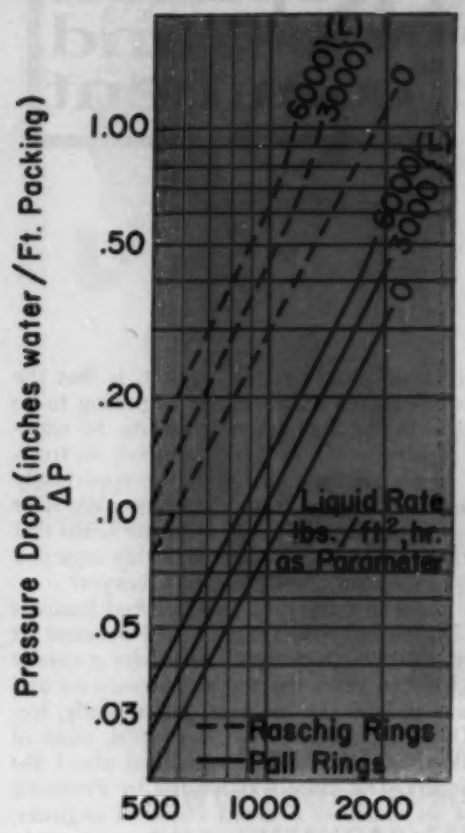
Perhaps what engineers need are spokesmen for their accomplishments to show management how they save in design, construction, and operation, and to prove that their contributions are as necessary to the sales and profits of the organization as are those of any other discipline. It has been pointed out many times in these pages that engineers usually work for other engineers. If the country is to continue to capitalize on the brains, training, and intelligence of the engineering talent that it turns out every year, it is up to every engineer to see to it that those under his supervision are paid well and are enabled to assume responsible positions. Otherwise it will continue to filter down that the high expectations of new engineering graduates are in vain. It is up to engineers to do something about the engineer's position.

F.J.V.A.

Cut Tower Volume 20% to 40%

with

METAL PALL RINGS



PRESSURE DROP vs. GAS RATE

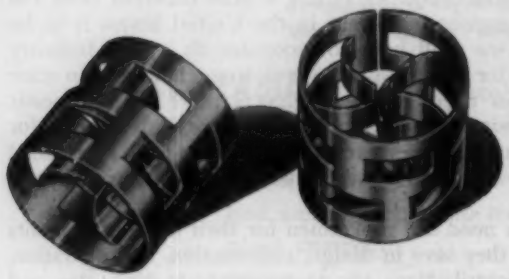
Where conditions suggest the use of metal packing rings in absorption operations, here's an important point to remember:

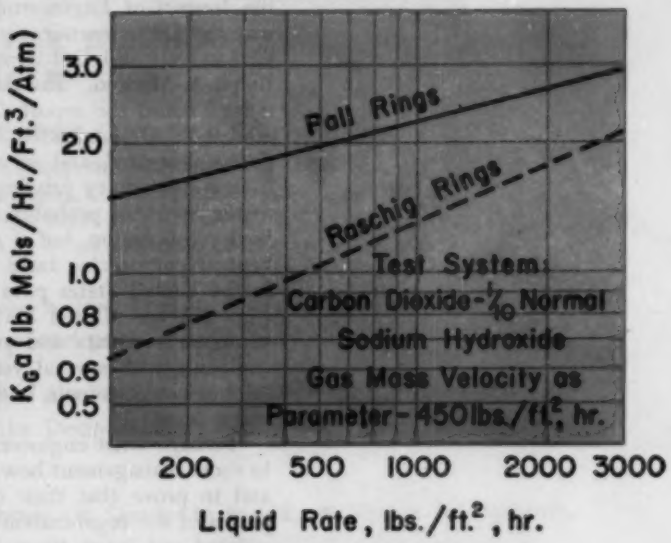
Tower volume can be reduced substantially by using metal Pall Rings in place of metal Raschig Rings.

Take a careful look at the graphs. They show capacity data and pressure drop data taken from tests run not in an eight or twelve inch tower but in our new 30" diameter experimental tower. The tests were made using 1½" rings, packed to a depth of 8 feet.

This improvement in performance results purely from the characteristics of the Pall Ring. The Pall Ring differs from the conventional Raschig Ring in that sections of the ring wall are stamped and bent inward permitting better circulation of liquid and gas. Thus, more surface area is wetted resulting in greater active contact area between phases.

Metallic Pall Rings are made at present in 1", 1½" and 2" sizes in carbon steel, stainless steel, aluminum and copper.





MASS TRANSFER COEFFICIENT vs. LIQUID RATE

For full information —

on Pall Rings and on other tower packings, write for a copy of Bulletin TP-54.

U. S. STONEWARE

AKRON 9, OHIO

For more information, turn to Data Service card, circle No. 106

International Licensing

Safeguard or roadblock! —part one

Licensing of patents to obtain wide and controlled use of the invention avoids the extreme of complete secrecy which was widely practiced in the earlier history of the U.S. and is still prevalent with regard to know-how and trade secrets.

To the chemical industry, with its huge research and development expenditure, its shifting markets, and its fast-moving price structure, the problems of International Licensing and Collaboration are acute. Traditionally, the chemical industry has leaned in the direction of secrecy—secrecy in processes, manufacturing, planning, even to the point of secrecy in plant capacities. There are many good reasons for these policies. On the other hand, the petroleum refining industry achieved its present size through tremendous growth aided by process licensing.

As chairman of the session at Kansas City, I would like to express my appreciation to the speakers and the audience for their cooperation in the success of this unusual session.

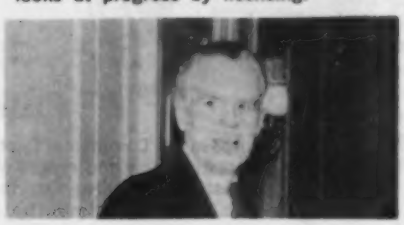
RALPH LANDAU

Ralph Landau, executive v.p. of Scientific Design, chairmaned the highly successful Kansas City Session he introduces here.

T. G. Gillespie, Jr. (left), chemical engineer, lawyer and v.p. of Scientific Design, discusses the legal aspects of licensing abroad.

Rauer Meyer (right), from the Dept. of Commerce, outlines and explains the Government view.

W. C. Asbury (below), a v.p. and patent chief for Esso Research, looks at progress by licensing.



The fourth aspect of this subject, **H. W. Knauff's** "Problems in International Licensing," will appear in July as Part 2 of the series.

New regulations affect... Technical Data export control

Rauer H. Meyer, *Director, Materials Div.*
Bur. of Foreign Commerce U. S. Dept. of Commerce

Since the much publicized Khrushchev letter of last June to President Eisenhower, and the recent visit to this country of Soviet Deputy Premier Mikoyan, U. S. technical data has come into the limelight. Particularly chemical engineering and process technology, for it is this advanced U. S. know-how that the Soviet Union desires.

"Technical data," as many of you already know, may be called the language of technology. It is the means of precise communication of technical thought. Its symbols, although somewhat varied and complex, are well standardized, and are acceptable internationally. This specialized language, however, in its advanced form is generally intelligible only to other engineers and technicians. The Department of Commerce defines technical data as "any professional, scientific or technical information of any kind that can be used or adapted for use in connection with any process, synthesis or operation in the production, manufacture, utilization, or reconstruction of articles or materials."

Under this definition, we consider any release of unclassified technical data for foreign use, regardless of where the release occurs, as an exportation of the technical data.

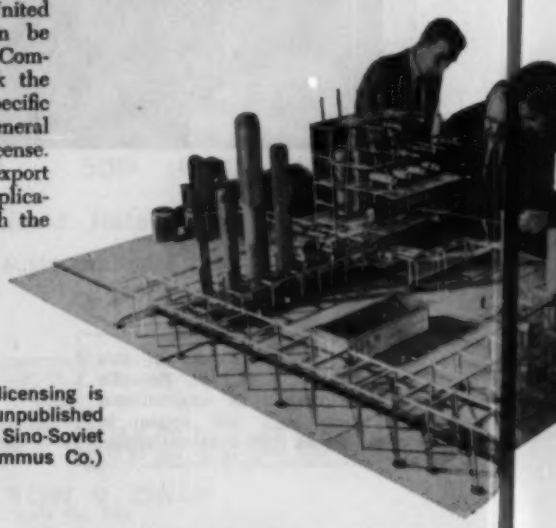
Government control of technical data

The "Export Control Act of 1949," as amended, declares that it is the policy of the United States to control exports to the extent necessary to (1) protect the domestic economy from excessive drain of scarce materials and to reduce the inflationary impact of abnormal foreign demands; (2) further the foreign policy of the United States and to aid in fulfilling its international responsibilities; and (3) exercise the necessary vigilance over exports from the standpoint of their significance to the national security. To effectuate this policy the President is authorized to prohibit or curtail the exportation from the United States of any articles, materials, or supplies, including technical data, except under such rules and regulations as he shall prescribe. The Department of Commerce by delegation from the President is the Government agency charged with the authority and responsibility for export controls over most of the goods and services involved in international trade. The Secretary of Commerce has delegated the administration of export controls to the Bureau of Foreign Commerce.

It is the function of the Office of Export Supply, within that Bureau, to administer this program effectively and efficiently. How do we do this? Our Export Regulations require that every shipment of commodities and technical data made from the United States to a foreign destination be licensed by the Department of Commerce. To accomplish this task the BFC has established two specific types of export licenses: The General License and the Validated License. The General License is an export license for which no formal application is required to be filed with the Government, and for which no Government document will be issued. This license is available for use by all persons, permitting exportation within the provisions of the Export Regulations. The Validated License is an export license that requires both the filing with the BFC of a formal application covering a specific transaction, and a document issued by the BFC authorizing exportation.

Inasmuch as my purpose here is to discuss Export Controls of Technical Data, I shall direct my discussion to that part of the Export Control Program. Our main concern in this program is the problem of exports from the U. S. of unclassified technical data. I say "unclassified" because the Department of Commerce does not control any technical data that has been officially assigned a security classification by another agency of the U. S. Government. In addition, Commerce has no jurisdiction over technical data relating to items on the Munitions List. This is the responsibility of the Office of Munitions Control, Department of State. The Atomic Energy Commission, of course, has the responsibility for controls of technical data relating to all fissionable material and/or equipment for the production and utilization of fissionable material. The control of all other unclassified technical data is the sole responsibility of the Department of Commerce.

As I stated earlier, the Government considers any release of unclassified technical data for foreign use, regardless of where the release occurs, as



Purpose of Commerce Dept. licensing is to restrict only the export of unpublished industrial technology to the Sino-Soviet Bloc. (Photo courtesy The Lummus Co.)

an exportation of that data.

In brief, this means that technical data need not actually be shipped from the country in order to accomplish an exportation. The furnishing of the data, in the U. S., to any person with the knowledge or intention that the person to whom it is furnished will take such data out of the United States, is an exportation of the technical data, and under our regulations requires a license.

How does the Government control technical data? Let me say first that it is not the intention of the Department of Commerce to initiate any form of censorship action. Moreover, the Department is not adequately staffed to review the exportation of the large quantities of technical data that are being sent daily from this country, even if we wished to. To answer the question, sometime ago the Department of Commerce, in consultation with other interested Government agencies, initiated what is commonly known today as the "Technical Data Licensing Procedure." These regulations, a part of our Comprehensive Export Schedule, permit unclassified technical data to be exported from the United States under four specific licenses: General License GTDP, General License GTDS, General License GTDU, and the Validated export license. The first two of these licenses, GTDP and GTDS, deal with unclassified technical data that may be sent freely throughout the world. The third, GTDU, covers technology which can be sent freely to friendly countries under certain specified conditions, but requires a validated export license to send the data directly or indirectly to the Sino-Soviet Bloc.

It should be noted here that the United States Government maintains a complete embargo over the shipment to Communist China of both commodities and unpublished technical data falling under general license GTDU.

General licenses

The General License GTDP covers all unclassified technical data generally available in published form, and includes such data that is either sold at newsstands or bookstores; available without restriction to any person by subscription, purchase, without cost or at any public library; or granted second class mailing privileges by the U. S. Government. This data may be exported to all countries without restriction.

The General License GTDS covers all unclassified scientific and educational data, and includes all such data not directly and significantly related to design, production and utilization in any industrial process. Also covered is instruction in academic institutions and academic laboratories. Such GTDS data may be exported to all countries without restriction. This license does not cover any instruction that may be defined as research under contract, where the research relates directly and significantly to design, production and utilization in industrial processes.

The General License GTDU covers all unclassified technical data either unpublished or not generally available in published form. This license covers technology and know-how that is the unique possession of engineers and private industrial organizations, being of a proprietary nature and usually listed among the capital assets of the company. Under this license you may send data under certain specified conditions to any *non*-Sino-Soviet Bloc country.

Exports to the Sino-Soviet Bloc countries of technical data that do not come within the scope of General License GTDP or General License GTDS, require a validated export license.

Because many American firms are concerned with the question of releasing data of possible strategic significance even to friendly countries, the Department has established a procedure whereunder an American firm desiring an official Government opinion on the desirability of releasing such data for use in a friendly country, may obtain an opinion by writing to the Department of Commerce. This is known as the "Voluntary Plan" and is concerned with any technical data that may have significance to the common security and defense of the United States.

Presently, we receive approximately 120 requests monthly from various U. S. companies asking for such opinions. Normally, the Government interposes no objection to the release of such data, and in the few instances when we have objected, there has been a valid security reason for doing so.

Now, you will recall that in describing the General License GTDU, I stated that under *certain specified conditions* you may use this General License to send this type data to any non-Sino-Soviet Bloc country. The most pertinent example of an exception to General License GTDU is to be found in a recent Government action, which will become effective June 8, imposing additional restrictions on the export of technical data either unpublished or not generally available in published form relating to certain petrochemical plants and processes. Specifically, these restrictions are that prior to making any exportation of technical data under

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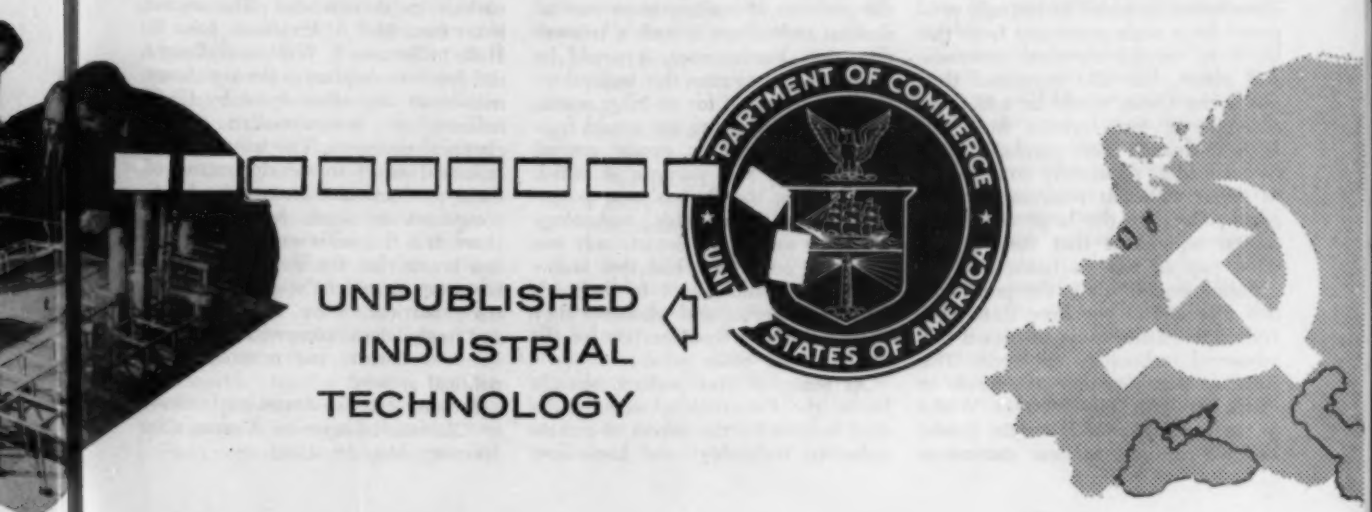

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General License GTDU, the exporter shall obtain written assurance from the importer that neither the technical data nor the primary product of that technical data is intended to be shipped, either directly or indirectly, to a Sino-Soviet Bloc destination. In addition, this General License shall not be applicable if at the time of exportation of the data from the United States the exporter knows or has reason to believe that the primary product to be manufactured abroad by use of the data is intended to be exported or re-exported directly or indirectly to a Sino-Soviet Bloc country.

There is also another *certain specified condition* to General License GTDU, which, while it may not involve this group, went into effect on June 1. This involves technical data relating to civil aircraft, equipment, parts and accessories and components; and certain electronic equipment. These data heretofore controlled by the Office of Munitions Control, Department of State, were transferred to the Department of Commerce jurisdiction on June 1.

As you can see from the General Licenses I have just described, it is the Government's intention to restrict only the exports of unpublished industrial technology to the Sino-Soviet Bloc countries. Our desire to control the release of this technology, to these destinations, is self evident. For Mr. Khrushchev and the Russians frankly admit a serious lag behind the Western World in the highly complex petrochemical fields. They, themselves, recognize that certain process and engineering technology can best be obtained only from the United States. Mr. Khrushchev's magic remedy for this situation can be found in his trade letter of last June to President Eisenhower, in which he not only proposed large scale purchases from the U. S. of various chemical processes and plants, but also suggested that the Soviet Union would be willing to accept long term credits from the U. S. to finance these purchases. The Soviet leaders apparently do not wish to divert sufficient reserves into exports to acquire the large volume of capital equipment that they desire, on a pay as you go basis, but are counting on appeals to the profit motive inherent in our Free Enterprise system to enable them to obtain this advanced technology on credit. The Russians state that they desire only to catch up with the Western World in the production of industrial goods. But we continue to hear statements from them that they will soon surpass us in total industrial production, and that their economic system will bury that of the capitalistic Western World. Let us not treat these statements too lightly, but let us examine closely the foreign trade policies of the Soviets. First and most important, the Soviets have established a state monopoly over foreign trade. This absolute state monopoly permits them to turn trade off and on in accordance with the Communist political strategy of the moment. Secondly, the economic well-being of the individual in the Soviet State is subordinated to the rigid demands of the State. The Soviets can export raw and some finished materials at prices that the Free World businessman cannot compete with. Witness the recent Soviet dumping of tin and aluminum, This is illustrative of what could occur in the future, and is one of the major reasons why the problem of trading away our industrial technology is such a tremendous one. Furthermore, it would be foolish for us to give this technology to the Russians, if for no other reason but that by so doing we would frustrate our commodity export control program, the sole purpose of which is to reduce the Soviets' war potential. In addition, this technology would be sold to the Soviets only one time, for once they had this know-how they would use it to their advantage wherever and whenever they wished, without consideration for the rights of any other person.

As many of you perhaps already know, the Government recently denied licenses for the export of certain industrial technology and know-how to the Soviet Bloc. This action was taken only after a most intensive and comprehensive study of all facets of this problem involving the major departments of the Government. It was determined that the Government policy at this time would not permit the export of any product or technology that could be used to aid the Soviet military potential either directly or indirectly. The Government, in making its decision on this problem, also sought the advice of private industrial companies.

You are no doubt familiar with the recent statements of the Manufacturing Chemists Association advising that Mr. Khrushchev's proposition is dangerous to the Western World, and that the Government should not relax its policies on control of U. S. production know-how or plants to the Soviets, but should strengthen these controls and seek the assistance of other Western nations to do likewise. The recent letter from M.C.A. President, John E. Hull, to Senator J. William Fulbright did much to emphasize the significant man-hours and effort spent by U. S. industry to commercialize certain chemical processes. The scientific and technical effort to develop some of these products has taken some U. S. companies as much as 2,100 man years. It is this achievement of American brains that the Russians wish to buy from us under the guise of easing trade barriers, while their scientists and technicians concentrate on devices to destroy our economic and political system.

Presented at the American Institute of Chemical Engineers Kansas City Meeting, May 18, 1959.

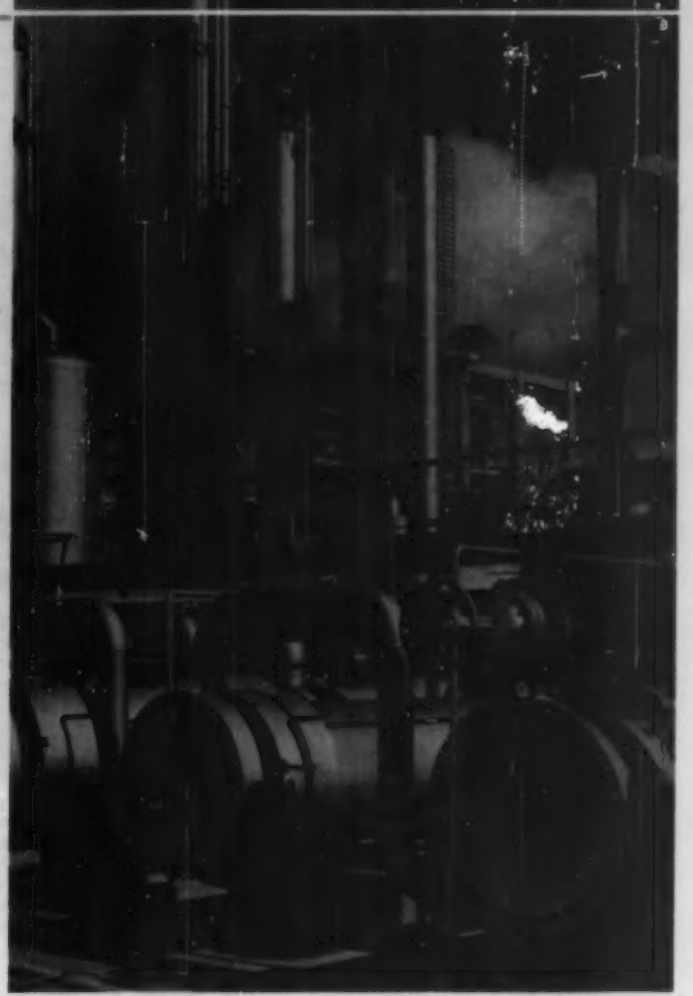
	Formal Applications	Kind of Data	Export Area	Special Situations
GTDP General License	none required	Published Technical Data	All Countries	
GTDS General License	none required	Published Scientific & Educational Data	All Countries	
GTDU General License	none required	Unpublished Technical Data	Friendly Countries	Petroleum and petrochemical plant, equipment, process data and products cannot be transhipped to the Sino-Soviet Bloc.
Validated Expert License	File with Bureau of Foreign Commerce	Unpublished technical data relating to petroleum or petrochemical plant, equipment, process data or products.	Friendly Countries	When there is no written assurance from the importer that the material will not be shipped directly or indirectly to the Sino-Soviet Bloc, or when the exporter knows or believes that the end product to be produced abroad is intended for the Sino-Soviet Bloc.
Validated Export License	File with Bureau of Foreign Commerce	Published & unpublished data not coming within scope of GTDP or GTDS licenses	Sino-Soviet Bloc Countries	

A quick reference guide to export licenses. (All exporters should consult published regulations for actual details.)

Petroleum processing

Progress through licensing

W. C. ASBURY
Esso Research and Eng. Co., Linden, N. J.



The CAA Butadiene Extraction Process used in this 50,000 ton/yr. Baytown, Texas, plant of Humble Oil, is licensed by Esso Research and Engineering. (Photo courtesy Esso Research.)

THE gasoline we burn in our cars today is far superior in octane number, and every other desirable property, to the product that was made only thirty years ago. Improvements in products and processes have been attained both by companies with large research organizations and those with small research groups, yet the cost, not including taxes, has changed very little in spite of the effects of inflation. The ready availability of efficient processes, through licensing, has contributed to this cost control.

A few decades ago, refining was a very simple procedure. It involved, mainly, the distillation of the various fractions of crude oil. Today, for making the major products, there are about 100 licensed refining processes available to refiners throughout the free world. In the future, we can expect process licensing and the patent system to continue making important contributions to progress. Yet there are some factors that could change this favorable climate.

A. Weakening (or even abolishment) of the U. S. patent system.
B. Compulsory licensing legislation.
C. An increase in anti-trust hazards to licensing.
D. Failure of royalty rates to provide reasonable returns.

A serious attack on the patent system would have an adverse effect on the present licensing practice in the oil industry and the technological progress that has accompanied it. If confidence in the patent system is lost, or if the system is abolished as some people have advocated, there could be a return to the ancient system of protecting information by secrecy.

Under the present patent system, people who do research work feel freer to publish the results of their work if they can rely on their patents for protection. The patent itself is a publication. The technical men employed by industry to make discoveries gain a great deal by being able to discuss and publish their achievements freely. A study of the history and the conditions today in the petroleum industry illustrate that the patent system is doing what it was designed to do.

Another factor which could have a profound bearing on licensing processes is any universal system of com-

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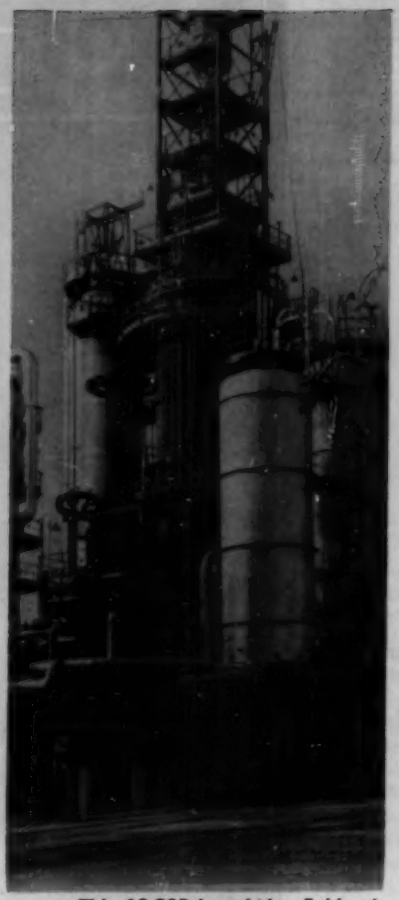
pulsory licensing. The question might be raised as to how a universal compulsory licensing system differs from the general licensing situation in the oil industry. First and foremost, is the fact that the present system is voluntary and allows people flexibility and freedom of choice that would not be present in a broad compulsory licensing system. In addition, a compulsory licensing system could work hardships on individual inventors and small companies trying to launch a new product or new device on a market and needing a period of competitive advantage to become established in the market.

Compulsory licensing legislation would, to a certain extent, operate the same as abolishing the patent system. It is doubtful that researchers would be as willing as they are now to patent their inventions if it meant they would be placing such patents under a compulsory licensing arrangement.

Compulsory licensing would also seem to lead inevitably to some sort of regulation of royalty rates. This regulation would probably be in the nature of a ceiling; it would certainly not be a floor. The bargaining position of the patentee who is forced by law to license his patent is necessarily weak, and his royalty structure is therefore likely to erode, perhaps even to crumble. This would be an incentive to keep inventions secret rather than to patent them at all. That is why I believe that compulsory licensing must, to some extent, be regarded as a proposal for abolishing the patent system.



This 10,800 barrel/day fluid catalytic cracking plant of Lion Oil (Monsanto) at El Dorado, Arkansas, uses a Fluid Catalytic Cracking Process licensed from Esso Research and Engineering. (Photo courtesy Esso Research.)

The largest Orthoflow fluid catalytic cracking unit ever built is this 102,000 bbl./day unit at Tidewater's Delaware refinery, has its Orthoflow license from a large group of companies.

Mutual benefits

Today's refiner, whether he be small or large, can choose from a wide selection of processes and techniques that are available through process licensing.

Which is to say, that for manufacturing the major products there is nothing to prevent a refiner from getting the process and operating know-how he needs, if he is willing to pay reasonable royalty rates for the processes involved. In return for royalties, oil companies here and abroad have traditionally made their basic processes available to other oil companies throughout the free world. This may seem strange until one considers that the major goals of oil company research departments are largely the same: better processes for better fuels and lubricants. Consequently, it is natural that the research results overlap, or conflict, depending upon how one looks at it.

This overlap has had two results which have influenced the licensing policy in the oil industry:

1. If one company develops a "better" process for making a fuel or a lubricant, it is more than likely that other companies have competing processes in some stage of development. The first company will therefore not gain much permanent advantage by keeping its process to itself. It might just as well license that process to the rest of the industry and obtain whatever royalty income it can. Otherwise, one of its competitors will follow that route and obtain the benefit of royalty income.

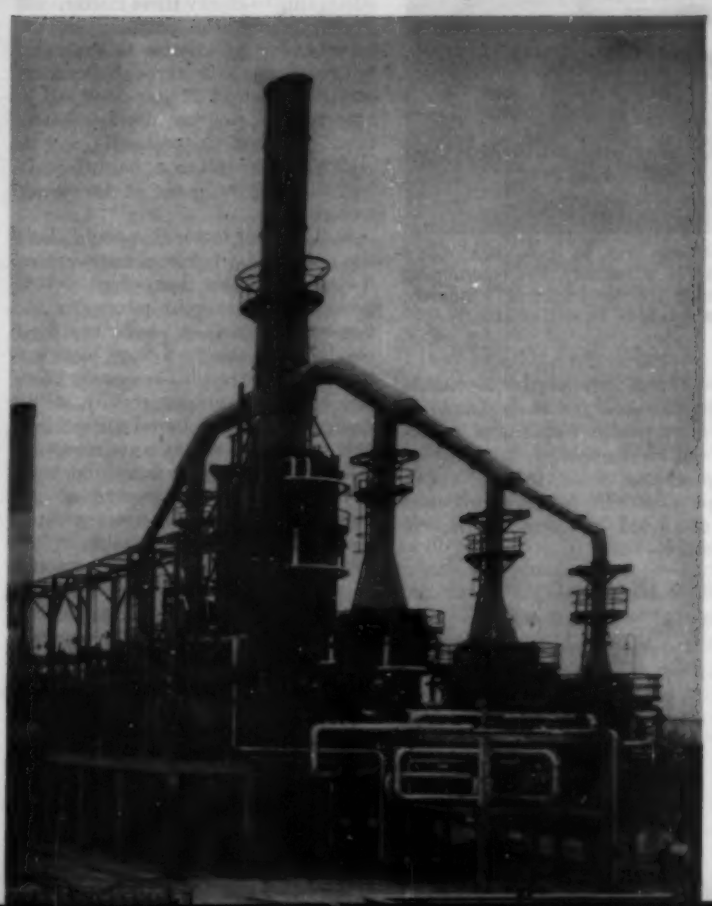
2. Often a company that has developed a process and obtained a patent coverage on the process will, at some stage in the development, find itself faced with patents of another oil company working along somewhat similar lines. In such a case, the process cannot be made fully available to others in its preferred, operable form without licenses from both the companies. Modern practice is such that one of the two companies will purchase a non-exclusive right from the other to license the other company's patents with its own.

It may be recognized that licensing is not practiced to this same great extent in the chemical industry, because of some basic differences in the two industries. In contrast to the petroleum industry, the chemical industry is more diversified, and deals with smaller volumes of products, except for the basic chemicals such as: sulfuric acid, ammonia, and the like. Furthermore, it produces a wide variety of chemicals for a myriad of different applications, and as a result, a process developed by one chemical company will have limited interest to others.

The past two decades have seen the rapid development of a rela-

Photo courtesy American Petroleum Institute

An 8,000 bbl./day Powerforming unit at the Esso Standard S.A.F. Bordeaux, France, refinery. The Powerforming process is licensed from Esso Research and Engineering. (Photo courtesy Esso Research.)



tively new, hybrid industry; **petrochemicals.** The licensing policy in petrochemicals may also be described as a hybrid between the traditional policy of the oil industry and that of the chemical industry.

Generally speaking, there is not the same broad availability and variety of processes in the petrochemical field that there is in conventional refining. Even so, oil concerns have made a large number of their petrochemical processes available under licensing arrangements.

How it happened

No doubt a most significant influence on licensing activities in the oil industry was brought about by the World War II effort. Under the auspices of the Petroleum Administration for War, information on certain processes was pooled to provide maximum supplies of aviation gasoline.

As a result, process information and patents were available from work pooled for the benefit of the war effort, with the Government departments concerned sponsoring the necessary anti-trust clearance from the Department of Justice. The purpose was to make important basic processes generally available for use by those who needed them, in return for suitable royalties to the companies who supplied the process rights.

The situation today

In process licensing today, a prospective licensee is interested in obtaining a process or technique that will do the job he wants it to do. He wants to be sure he gets patent rights, technical information, and performance. He wants to be sure that he is getting protection, not only under all the existing patents he needs today, but also those which may issue on improvements in the process for some years in the future. He wants a complete process design and the basic information necessary to build and operate the plant or processing unit. In many instances he wants guarantees that the plant will operate as expected. Often, he also wants assistance in starting-up operations and training employees. He may even want a **hold-harmless agreement** that will protect him against serious infringement suits by other patent owners.

In meeting these requirements, today's licensor faces some real hazards. One such hazard in today's rapidly changing world is the possibility that a licensed operation will infringe some patents of others which may not even be issued yet. Here is where the defense and hold-harmless provisions of the license come into play. The licensor can spend considerable time, effort, and money defending the licensee and holding him harmless. This may frequently involve buying some additional rights to protect the licensee. Although the licensor may at first be involved in licensing only his own patent rights, he may soon find himself involved in licensing the rights of others.

To mention another controversial subject that helps to keep licensors awake nights, consider so-called **package licensing.** The newspapers mentioned this recently in the government suit against RCA. Package licensing usually means that the licensor insists the licensee must take all of the patent rights, and does not have the opportunity to pick and choose only those he wants. The question has been raised: Is it the same thing when the licensor consents to break the package but refuses to reduce the

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Process licensing

continued

price? This is a subject on which even two Federal courts appear to be in sharp disagreement, and it is not appropriate to try to consider it here. Suffice it to say that you had better discuss it with your lawyers if you suspect you have any problems.

The oil industry's practice of process licensing has certainly minimized the anti-trust hazards. The proof of this is the relative absence, in recent years, of anti-trust suits based on the licensing practices in the oil industry. Incidentally, another current licensing practice in the world-wide oil industry, is to license the manufacture of a product under the patents of the country in which the plant is to be located, with the right to use and sell the product in any country of the world. This automatically helps to eliminate the possibility of certain types of anti-trust complaints which may arise in connection with more restrictive practices regarding the use and sale of the product.

Why do people license?

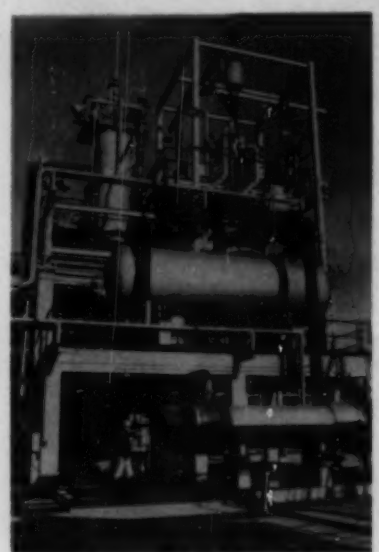
In view of the hazards just mentioned, perhaps we should now ask, "Why do oil companies go into the licensing business?" It can be explained this way: Consider that under our present patent system, industry finds it prudent to get patents to protect its investment in research. There would certainly be little incentive to do R&D work if others could use the results without any expenditure or efforts of their own. In most industries where substantial amounts of research are being done, patents are obtained. If this research results in a commercial process, or processes, protected by patents, then (as today's practice indicates) there is a natural incentive to offset some of the research cost by licensing for royalties at competitive rates.

The question is often raised: "Why does an oil company sell licenses for its processes when the royalty income it can obtain from licensing is small compared to the profits obtainable by using the process itself?"

One very good reason is that an oil company in the business of selling licenses is also a buyer of licenses; it earns substantial operating profits by the use of processes it licenses from others. It cannot expect to remain in a position to buy such licenses if it is unwilling to sell licenses for its own processes. This is borne out by the wide availability of licensed processes mentioned earlier.

Research in the oil industry is now growing at a rate of some 12% per year. In 1958, the oil industry spent about $300 million for all forms of research work. Obviously, such expenditures and effort to produce technology result in the need for patents and widen the possibility of more patent controversies. There have been many instances in the past where several companies have come out with similar developments at almost the same time; as if the need for a new product or a new process had become so urgent, that several inventors in different organizations, working independently, arrived at the same results at about the same time. In any case, patent interferences and patent controversies may arise.

This tendency will increase in the future as long as our present atmosphere for research and patents continues. These controversies inevitably lead to the need for an exchange of licenses to permit freedom of operation, and unhampered licensing of new processes which, in turn, assure prompt availability of new processes and continued progress in the oil business.



Hydrofining unit at Esso Standard's Bayway, N. J. refinery. The Hydrofining process is licensed from Esso Research. (Photo courtesy Esso Research.)

Benefits to industry in licensing

It is interesting to note that during the last ten years, the total processing capacity owned by smaller, non-integrated firms has grown at a much faster rate than the total capacity owned by the larger, integrated companies. M. J. Rathbone, president of Standard Oil Co. (New Jersey), said recently that our former ideas of the maximum efficient size for refineries have been revised downward sharply by technical developments for the past ten years.

The wide availability, through licensing, of refinery processes has been a major factor contributing to these changes. The smaller companies have saved themselves the expense of research and development on refining processes. In many instances, these companies have adopted the new techniques available to them through licensing as promptly, or even more promptly, than the larger companies.

Those who engage in licensing activities know that they are fraught with anti-trust hazards, but they undoubtedly believe in competition, and therefore in the anti-trust laws. However, it is sometimes impossible for legal counsel to give a definite answer when an anti-trust question arises. The answers are not to be found in the anti-trust statutes because of the vagueness with which the statutes are written. Even when previous cases are studied, numerous questions are left open. Worse still, decisions are occasionally in conflict. This uncertainty is often a hindrance to business.

Therefore, if future court decisions attempting to clarify these matters still further restrict the flexibility of the licensor, his willingness to make his processes available through licensing may be impaired. If you don't sell licenses at all, you are not faced with these questions. Consequently, any increase of the anti-trust hazard could well push licensing out of the picture entirely.

Still another factor that could affect the current favorable climate is that the royalty rates themselves fail to provide an adequate return to the licensor. In the oil industry, most royalty rates are on a fixed basis per barrel; for example, so many cents per barrel of running royalty, or so many dollars per barrel of paid-up capacity. These rates do not recognize inflation as do rates based on sales price (usually a percentage of the sales price.) If royalty rates are not commensurate with the value of the process, people doing a large amount of research work will not be able to justify their licensing efforts, particularly if the licensing permits competitors to enjoy the fruits of research work at an unreasonably low price.

Presented at A.I.Ch.E. Kansas City Meeting, May, 1959.

The Law and Foreign Licensing

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One of the firsts aspects of foreign licensing that needs to be considered on the part of an American licensor is his relationship with the Federal Government. This can be broken down into three areas. The first of these merits only passing consideration in that it is obvious that the atomic energy legislation places considerable restriction on any prospective licensor and is, in essence, a Governmental function.

The second area is the export control of technical data. This is a function of the Bureau of Foreign Commerce of the United States Department of Commerce. In the event one desires to export technical data, an application for export license is made. The definition of technical data is ". . . any professional, scientific or technical information, including any model, design photograph, photographic negative, document or other article or material, containing a plan, specification or description or technical information of any kind which can be used or adapted for use in connection with any process, synthesis, or operation in the production, manufacture, utilization, or reconstruction of articles or materials". This embraces anything that the chemical engineer customarily speaks of as "know-how".

A third consideration is found in The Patent Codification Act, Section 181 of Title 35 of the U.S. Code, which permits issuance of secrecy orders by the Commissioner in instances in which the publication or disclosure might be detrimental to the national security. Further, Section 184 requires a license to be obtained for filing in foreign countries if prior to six months after the filing of the application in the United States. In the event no secrecy order is issued within six months after filing, there is an automatic grant of a license to file abroad.

Foreign patents in U. S.

Looking at the patent system of the United States of America through the eyes of a foreign prospective licensor, it is interesting to consider a comment from a foreign source that the patent system of the United States is as bad as that of the Soviet Union. Of course, in the Soviet Union, there is no incentive for a foreigner to obtain a patent, as he will not be able to realize on it. I have heard the comment from a foreign source in exactly the same vein and referring to the United States patent system. This startled me. It arose out of a consideration of the practicalities of obtaining a patent in the United States in sufficient time to secure for a foreign inventor a firm competitive position. The foreign company which has launched into the commercialization of a new chemical product or process that is of considerable commercial value will often find itself beset, not alone by active competition in the United States by the U.S. companies, but will be frustrated by being thrown into interference with one, or more likely, a plurality, of applications filed by American inventors on inventions arising out of the basic idea.

The problem of settling an interference is somewhat complicated, and can be both very expensive and time consuming. Further, no patent can issue until the termination of the interference proceeding which decides which of the contending parties is, in fact, the first and original inventor. During the pendency of an interference proceedings no patent exists, and one cannot take any legal steps to prevent another party from practicing the invention for which he has applied. The foreign discoverer is not able to skim off the cream as he expected and, as my foreign source remarked, this peculiarity of the American patent system ties up such inventions during the time when there is still cream on the top of the bottle.

A foreign applicant involved in an interference generally can only rely on the date of filing his application in a foreign country for proving an early date to establish priority of conception of the invention. This arises from the fact that, under United States laws, *only acts performed in the United States can be used to prove conception and reduction to practice of an invention.* An American inventor can produce evidence of the conception of the invention earlier than his filing date in the United States. This evidence can be in the form of memo-

continued

Licensing laws

continued

randa, laboratory notebook entries, oral disclosures to co-workers and the like. The foreign applicant does not have this advantage.

The Treasury Department

Another important aspect for consideration is found in the regulations of the U.S. Treasury Department in its foreign assets control program under Title 31 of Federal Regulations, Chapter V, Part 500-2.1 (*1*). This deals with transactions involving certain foreign countries and concerns itself principally with "property". The countries specifically dealt with in one set of regulations are China and North Korea and the prohibition is against "all dealings in, including, without limitation, transfers, withdrawals of exploitations of, any property or evidence of indebtedness or evidence of ownership of property by any person subject to the jurisdiction of the United States . . ." and the term "property" specifically embraces "contracts or licenses affecting or involving patents, trade marks or copyrights" and "any other property, real, personal or mixed, tangible or intangible . . .".

Foreign Governments

The foregoing has treated of the United States Government. However, one needs to consider the various aspects of legal relations of licensor and licensee with foreign governments.

One of the first considerations is the need for complying with the currency regulations. This has, in the past, been a problem of considerable concern to the prospective American licensor. In the past, in countries which have "soft" currencies, exchange has been difficult and remittances of dollars generally have had to have the approval of a governmental agency. With the recent devaluation of the French franc, there has been an easing of restrictions with respect to convertibility in a number of countries in Europe. The full import and impact of this move cannot be assessed at the moment, but one can look hopefully forward to much freer interchange of currencies which is most desirable on the part of both licensor and licensee.

The question of whether or not a prospective licensor is doing business in a particular country can have a very serious consequence, particularly with respect to taxes. If there are performances, such as servicing of a license, in the proposed license deal; one must consider whether or not employees may be required to visit the particular country and thus comply with particular rules and regulations.

One of the legal aspects which deserves most serious consideration on the part of an American licensor is the anti-trust law of the United States. It is impossible, within the limits of this paper, to give anything that approaches a proper treatment of the many pitfalls which exist for the unwary. These pitfalls can only be avoided by use of competent legal advice before action is taken. On the advisability of consultation with your lawyers before action is taken, I would only comment that the Department of Justice has its choice of criminal or civil proceedings in the case of anti-trust violations, and has been known to offer strong argument that jail sentence be imposed.

To me, treating the subject with a very broad brush, the anti-trust laws are, and I mean no irreverence, somewhat akin to the Ten Commandments. They consist principally of a series of "thou-shalt-nots", and are, indeed, delivered from Olympian heights beyond the comprehension of mortal men.

The Sherman Anti-trust Act condemns "every contract, combination in the form of trust or otherwise, or conspiracy in restriction of trade of commerce, among the several States or with foreign nations . . .". Thus, clearly, the basic anti-trust statute reaches into foreign commerce. This point need not be belabored because successful action has been taken against U.S. companies engaged in agreements with foreign companies as well as against a foreign company which happened to be within the jurisdiction of the U.S. courts.

> . . . One of the legal aspects which deserves serious consideration on the part of an American licensor is the anti-trust law of the United States.

A recent example of action against a U.S. corporation is the consent decree in U.S. vs. Combustion Engineering. This case named twelve foreign corporations as co-conspirators. The consent decree embraces a series of thou-shalt-nots, directed to Combustion.

With respect to foreign companies against which action was taken under the anti-trust laws of the U.S., there is the litigation involving I.C.I. and duPont. The U.S. Government proceeded against I.C.I. and duPont and enforced cancellation of agreements dividing territories and pooling technical knowledge. The decree of the U.S. court required that the agreements be cancelled, and that the companies divest themselves of interest in certain jointly-owned subsidiaries. A further very interesting aspect of this litigation was a proviso in the decree which required I.C.I. to assign to duPont the British nylon patent which had originally issued to duPont. It so happened that this patent had been exclusively licensed to British Nylon Spinners. This company filed suit in British courts to enjoin I.C.I. from complying with the decree of the U.S. court as being in derogation of the existing license. The suit was successful. The decree was appealed by I.C.I. and the original decision was upheld by the appellate court. Thus, we have the interesting situation of an American judge telling I.C.I. to do one thing, and a British judge telling I.C.I. not do what the U.S. judge says to do.

It might be well to examine certain principles underlying the anti-trust law. First of all, there has been a rule of long standing known as the rule of reason. That is to say, the courts do not adhere to the strict letter of the law which damns any restriction of competition, but rather hold that agreements and courses of action are illegal only when there is unreasonable restraint of trade. One exception to this reasonableness rule is the division of territories. This appears to be illegal *per se*. While the U.S. courts have held that price-fixing on patented articles is not illegal under certain rather specific conditions, the fixing of prices on an unpatented article is illegal. Agreements which restrict the right of a party to export or import from or into the U.S. are within the purview of the prohibitions of the anti-trust statutes.

Except for temporary statutes during military occupation, none of the countries outside the United States have anti-trust laws which are comparable to those of the United States. On the contrary, certain countries have a well known favoritism for cartels which, of course, are the antithesis of the philosophy behind the anti-trust laws of the United States.

One newcomer to the anti-trust scene is the European Common Market and the anti-trust aspects involved

in that treaty. These are, as of the moment, of unknown effect in application. One can read the words of Article 85, and related articles, and arrive at certain conclusions, but these are largely individual interpretations and have no authoritative backing in that the Common Market Treaty provisions have not yet been implemented by any rules and regulations. However, the treaty articles do seem certainly to have a potentially very strong anti-trust tone. Bear in mind that Article 85 prohibits any agreements between enterprises, decisions by enterprises to associate, or any concerted practices which are *likely* to affect trade between the member states, and which have as an object, *or* result, the prevention, restriction or distortion of competition within the Common Market. This language occurs in the first part of Article 85 which then goes on to particularize the certain items which are forbidden, as follows:

(a) the direct or indirect fixing of purchase or selling prices or any other trading conditions;
(b) the limitation or control of production, markets, technical development or investment;
(c) market sharing or the sharing of sources of supply;
(d) the allocation to parties to transactions of unequal terms in respect of equivalent supplies thereby placing them at a competitive disadvantage; or
(e) the subjecting of the conclusion of the contract to the acceptance by a party of additional supplies which, either by their nature or according to their commercial usage, have no connection with the subject of such contract.

Looking these over, one can certainly see many analogies with the U.S. anti-trust laws. The Common Market provisions outlaw suppression of competition, price-fixing, tie-in sales and the like. Now, these certainly can have very serious implications, and the seriousness with which they are considered can be seen in that, a little over a year ago, the International Chamber of Commerce urged on the members of the Common Market a delay in putting the anti-trust provisions into effect. The International Chamber felt that the provisions of Article 85 were potentially discriminatory towards business concerns in countries not members of the Common Market, and that they would actually ban a wide range of business agreements in the field of international trade.

One thing in particular that concerns me is whether or not the granting of an exclusive license on a patent in one of the member countries might be considered to be, as Article 85 states, "an agreement which would affect trade and has as its object the prevention, restriction or distortion of production". There is no argument that the granting of an exclusive license under, for example, a French patent, would have the effect of restrictive competition in the common market. One is left to wonder whether or not one can now grant an exclusive license on a patent in one of the member countries. We have the situation of one of the member countries granting a patent giving exclusive rights, and then having the Treaty cast the shadow of doubt upon one's ability to use this exclusive right.

Another general topic for consideration is taxes. When considering the legal aspects of foreign licensing, we must consider not the U.S. taxes alone, but also the impact of any foreign taxes which may be levied, and how they will affect the tax structure of the American licensor.

Basically, we are all familiar with the general tax structure in the United States and, in the vast majority of cases, remember the magic or tragic figure of 52% on net corporate income. The question as to what is income under the U.S. tax law can certainly give rise to some very complicated questions in foreign licensing. The problem is not too difficult of resolution when the only factor considered is a bare license, and the royalty payments thereof, and the licensee is in a freely convertible area. In such a case, dollars come in when royalties are due, and thus no complications arise, whether or not the U.S. licensor is on the cash or accrual basis. On the other hand, if the licensee is in a blocked area, the tax consequences can be very serious for an American licensor depending whether it is on a cash or accrual basis. For example, if on the cash basis, it might well be that royalties would be blocked for some considerable number of years and then, all of a sudden, a very large sum be made available which would result in a large amount of tax. If this occurred in a loss year, it would be most fortunate, but consider the anguish and travail engendered if it occurred in a high profit year. With respect to an American licensor on the accrual basis, one can see the possibility of trouble in having a royalty payment due and thus income on the books while the accrual payment is blocked because of currency restrictions. These matters, of course, have arisen and been given considerable attention by the Internal Revenue Bureau with some amelioration of the problems of a licensor on the accrual basis.

If the desideratum is income to the American licensor in face of the known tax consequences, the best method of operation is direct licensing by the American licensor. If, on the other hand, the particular circumstances involved make it desirable to consider building up of income for foreign business expansion without being immediately subject to the U.S. tax or if, for example, it is desired to defer income subject to the U.S. tax, the foreign operating corporation type of activity suggests itself. In such an operation, a corporation meeting the stock-ownership test of a maximum 10% holding by any one stockholder or stockholding unit formed outside the U.S., and having no income from sources within the United States, undertakes the licensing and receives the proceeds thereof. There are a number of countries which have liberal laws with respect to tax on foreign income of corporations formed under their laws. For example, a corporation formed under the laws of Panama pays income tax to Panama only on that portion of its income which arises from business or investments in Panama. Corporations in the Bahamas pay no income tax. The number of ships flying the Liberian flag is a commentary on the fact that, under Liberian law, corporations are not obligated to pay corporate taxes.

In such an operation, the monetary returns can be built up and utilized for expansion of the business outside of the United States. On the question of deferring income, it can be seen that the payment or accrual of dividends on shares of a foreign subsidiary can be controlled by the American parent subject, of course, to any applicable taxes on accumulation of income.

An American parent can utilize, as a deduction against income, or as a Foreign Tax Credit against its own U.S. income taxes, the amounts paid as taxes to a foreign government by the foreign subsidiary, within the limits prescribed by the Code. The parent must, however, be consistent in whether a credit or a deduction is utilized. The problem which arises immediately is what is "income tax" for the foreign subsidiary, and this can be quite vexatious. There is sometimes a very fuzzy pattern between a turnover tax or a transactions tax or a tax

continued

Licensing laws

continued

on production on the one hand, and an "income tax" levied by the foreign government against a foreign subsidiary, on the other.

Another method of operating outside the U.S. is the Western Hemisphere Trade Corporation. Such a corporation must meet the strict requirements of the Code. The type of corporation takes its name from the fact that one of its requirements is that 100% of its business be done in the Western Hemisphere. The Western Hemisphere means North, South and Central America and West Indies. It does not include Bermuda or the Falkland Islands. In addition, 95% or more of the corporation's gross income must be derived from sources outside the United States. Alaska is (and was as a territory under rulings since 1955) an integral part of the United States, as is Hawaii. Puerto Rico and the Canal Zone are considered as "partly within and partly without" the United States for this purpose.

Place of sale is important, as is place of manufacture of the goods. In general, *both* manufacture and sale must take place outside the United States to come within the 95% rule, in the case of a manufacturing enterprise. But for a solely mercantile (buying and selling) enterprise it is sufficient if 95% of the sales are outside the United States even though the goods are 100% purchased in the U.S.

The advantage of the Western Hemisphere Trade Corporation procedure is that the tax liability to the U.S. is reduced by a special deduction, which causes the effective U.S. income tax rate to be 38% (on taxable incomes subject to full normal and surtax rates) rather than 52%. While this looks like a saving of 14%, one must remember that dividends to the American parent are taxed at the rate of 15%, so that actually, the 14% apparent saving reduces to something in the neighborhood of about 9% on after-tax income paid to the parent as dividends.

In the case of a Western Hemisphere Trade corporation, the nature of the business done, rather than the business purpose, determines eligibility for the special deduction. The statute intended to grant a tax favor to Western Hemisphere Trade, for good national purposes. Formation of a subsidiary to take advantage of the Western Hemisphere Trade special deduction is simply an election authorized by the statute and is not open to an inference of intention to evade taxes if the statute is fully complied with.

This is not true, however, in the case of a foreign subsidiary which does not qualify for the Western Hemisphere special deduction. Here, as in all business changes which change the tax situation (otherwise than to take advantage of an election conferred by statute), there must be a good business reason for what is done. The existence of a good business reason negatives the inference that the foreign corporation was organized or the activity undertaken for the purpose of evading United States taxes. It is, as a rule, perfectly proper to use those legal procedures which result in avoiding tax liability. It is not alone improper but sometimes results in a fine or jail sentence to evade the United States tax.

At this point I should note that I am not offering advice as to the formation of any business entity abroad. Anyone, including a lawyer, who advises or assists in the formation of a foreign corporation is required by the Internal Revenue Code to report that fact to the Director of Internal Revenue on a form called Form 959. In other words, see your lawyer first.

Trials and tribulations

Amongst the other trials and tribulations involved are the negotiations and the provisions of the license itself. The first thing to be settled is who are the parties to the license: these are the licensee and either the American licensor or a subsidiary as discussed above. Of immediate concern is the language of the license when the licensor is other than an English-speaking country. Any American lawyer, of course, prefers the English language and most often, this is possible.

I recall one such instance involving a Force Majeure provision, which is a provision reciting events which excuse the parties from performing their obligations. This includes such events as acts of God, war, strikes or labor disputes, civil disorders and the like. In the instance to which I refer, in preparing a text in French of a contract that had been worked out in English, a Force Majeure provision typical of Continental or code law rather than Anglo-Saxon law was inserted and everything went well until time for signature, when the officer who was to sign on behalf of the foreign corporation realized that the Force Majeure provision excused performance on the occurrence of *evenements imprevus*, which is broadly translated as unforeseeable events. The question arose in this gentleman's mind as to whether or not, for example, the fall of a government or the re-establishment of the Berlin blockade were actually unforeseeable events. He was so concerned about this that the contract was not signed until an understanding had been reached that the usual recitation of acts of God, strikes and the like, common to the Anglo-Saxon law, actually governed.

One job for an expert that must combine both the talent of lawyer and the technical person is the definition of the field in which the license is granted. This has consequences both with respect to patents and know-how and requires very careful attention. The definition of the field must be such that the patents which are intended and necessary are licensed, but care should be exercised that the breadth of definition given to the field in contemplation of an expected exchange of license rights or technical information should not be such as to be a catch-all which would be embarrassing at a future date and include inventions and discoveries not contemplated by the parties, yet within the actual and literal definition of the field.

Another point which may seem trivial at the time of execution of a document, but which can present problems in the event of litigation, is the method of execution. It is very desirable to have the license agreement, if executed in a foreign country, signed before an American consul and attested by the consul and signed in the U. S. before a notary public and attested by the consul of the country involved. This enables easy proof of the execution of the document in the event such must be proven in either a court in the U. S. or elsewhere. If this method of execution is not followed, one can be faced with the necessity of proving the signatures to a document perhaps years after the date of signature.

There are a number of books, treatises, services and the like on the contents of a foreign license. These present extensive check lists as to the various items that may be considered for inclusion and many provide specimen forms for various provisions. These few remarks are not meant to provide anything definitive as to what should go into a foreign licensing agreement, and I refer you to such works and your own attorneys.

Presented at the A.I.Ch.E. Kansas City Meeting in May, 1959.

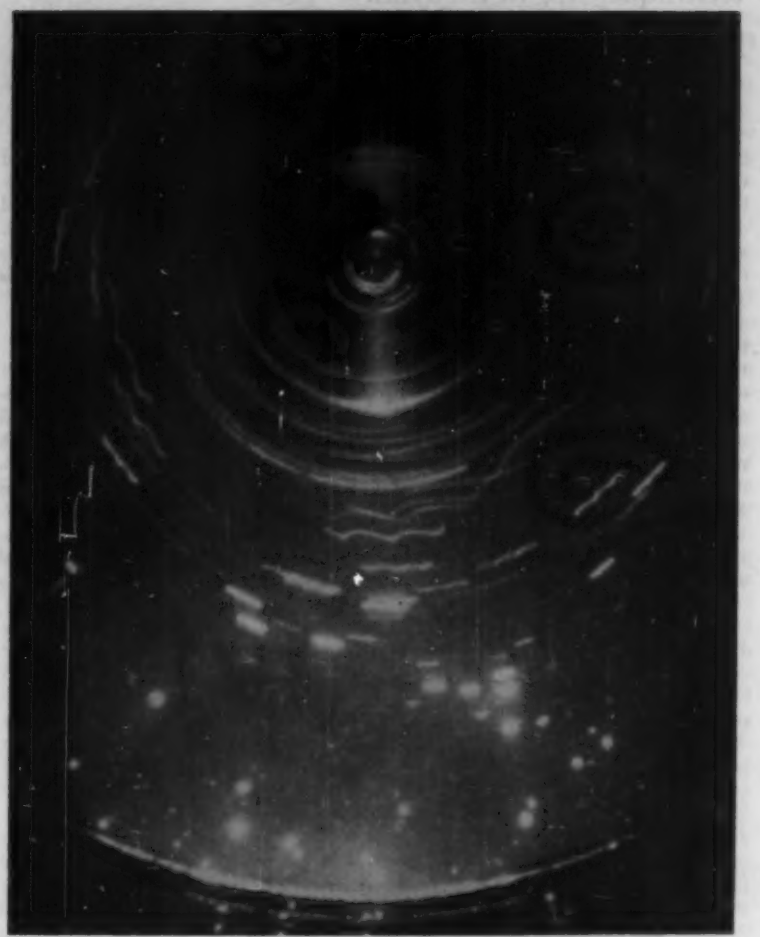

Figure 1. Flow Pattern in Agitated Vessel. Still photograph with ½ sec. exposure. Bottom view showing flow pattern set up by a 4-in. impeller rotating at 60 r.p.m. in a viscous, non-Newtonian liquid.

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high speed Photography *for chemical engineering*

MANY rapidly occurring engineering phenomena are susceptible to analysis by photography. The increasing skill with which chemical engineers use special photographic techniques in their research is demonstrated in the five papers reviewed here covering extreme conditions varying from single still shots of meaningful streak images of the desired objects, to the use of motion pictures taken at speeds as great as 1,500,000 frames/sec.

Flow patterns during mixing

A. B. Metzner and J. S. Taylor (*9*)

discussed mixing which occurs when a non-Newtonian fluid is agitated with a six-bladed impeller of 2-, 4-, or 6-in. diam. in an 11.3-in. diam. cylindrical tank. Two fluids, an aqueous solution of corn syrup, and an aqueous solution of sodium carboxymethyl cellulose (CMC), were used. The first is highly viscous, but is essentially Newtonian; whereas the second is decidedly non-Newtonian, with a flow behavior index of 0.50 to 0.60.

An important object of the study was to determine the flow pattern

continued

. . . high speed motion picture photography is no cure-all, and this tool should be used only when simpler techniques are to no avail.

continued

throughout the vessel for each liquid under a variety of test conditions. The motion was made visible by the use of suspended tracer particles having densities nearly equal to the liquid densities. A polymethyl-methacrylate molding powder was used most often, but some runs were made with 0.02-in. glass beads. A light beam, reflected at 90 degrees from the beads, made each bead appear as a moving pinpoint of light.

Motion picture photography was considered for this study and preliminary tests were made. However it soon became apparent that streak images on still photographs were easier to obtain and seemed to be just as productive of information. It is important to realize that high-speed motion picture photography is no cure-all and that this tool should be used *only* when simpler techniques are to no avail.

For a typical test, three still photographs at $\frac{1}{60}$ to $\frac{1}{4}$ second exposure were obtained. One looking up from the bottom gave streaks showing the motion of the beads projected in the horizontal x-y plane. For this exposure the illumination was a thin, rectangular light beam aimed horizontally, covering all of the x-y plane, but having a thickness in the z direction of only 3/16-in. Similar photos with appropriate changes in the light direction provided information on motion projected in the other two principal planes. From the lengths of the streaks of the bead images in the three photographs of the principal planes, it is possible to calculate the absolute velocity and direction of motion in space. From these values, local velocity gradients and shear stresses have been computed, and the local power consumption (power per unit volume) was calculated for numerous locations throughout the tank.

Metzner and Taylor found that the predominant mixing took place between the blades of the impellers. The fluid velocity dropped nearly to zero at short radial distances beyond the tips of the impeller blades. A typical case is illustrated in Figure 1, which shows the horizontal plane in a 1.2% solution of CMC agitated with a 4-in. impeller at 60 r.p.m. Continuous circular streaks identify the region of viscous flow between the blades. Steady pinpoints of light far out from the impeller indicate zones of negligible motion. The interesting scalloped streaks are caused by flow over or around and then behind the tips of the moving blades. A three-ridge scallop means that three blades passed the particle: thus some definite pulsating, in-and-out flow occurs in the region of the blades, in addition to the expected rotational flow.

Fluidized beds

L. Massimilla and J. W. Westwater (*12*) demonstrated the motions of individual solid particles in a fluidized bed. Air flowed upward through the solids in a 3.75-in. I.D. glass column. Extension tubes connected to the lens of a Wollensak Fastax camera permitted full-size images on the 16 mm. motion picture film. The individual particles were easily visible during

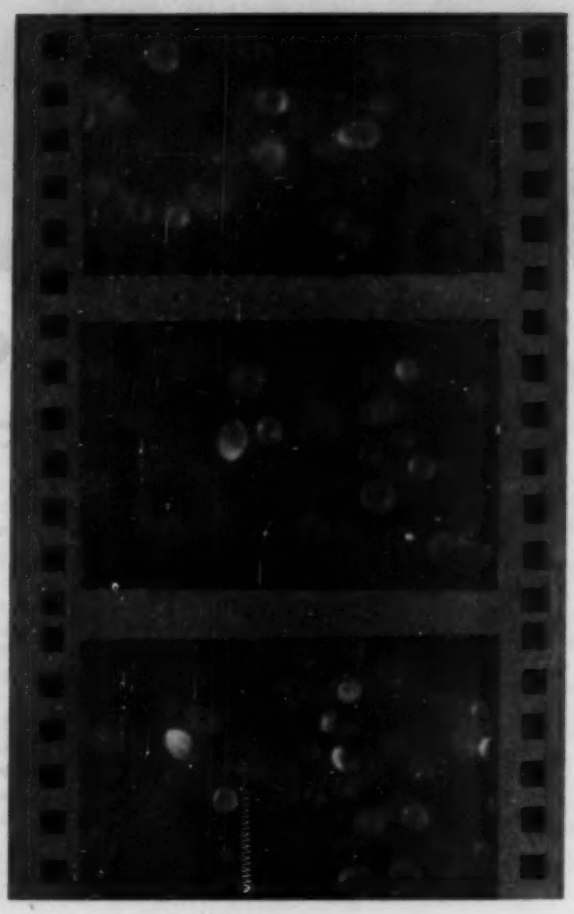

Figure 2. Fluidized Bed. Selected frames from a motion picture at 1800 frames/sec. Top to bottom (a) Frame 0, (b) Frame 8, (c) Frame 15. Field of view = 0.33-in. high. Glass beads, 0.028-in. diam., fluidized with air.

projection. About 5% of the particles were dyed black and served as tracers.

Glass beads of 0.028-in. diam. photographed at 2000 frames/sec. showed that the particle motion near the wall is predominantly downward. For short times the motion is also upward or sideward. Occasionally, all the particles in the ¾-in. high field of view were moving in random directions. The effect was like an assembly of gas molecules. Numerous collisions occurred, and many particles rotated rapidly. Figure 2 shows that the rotation is particularly obvious for elliptical particles. The one shown in the figure was spinning at 105 r.p.s.

Occasionally, all the particles in view moved simultaneously, in the same direction, and at the same velocity. The velocity of these aggregates, sometimes upward, and sometimes downward, was often five to ten times greater than the upward superficial velocity of the gas.

Horizontal screens of ¾-in. mesh, placed at 1 cm. intervals in the column, resulted in a pronounced change in motion and density. Without screens, the local density in the bed varied over a continuous spectrum, from the gas density, to the density of the solids in close packing. With screens, the bed density remained rather large and uniform. The particles were in close contact for relatively long times.

A bed of alumina powder of 120 to 200 mesh was useful for demonstrating bubbling and slugging. An important observation was that slugs, or large bubbles of gas, do not pass unchanged through a bed. During the rise of such a gas pocket, a steady rain of particles falls through the slug. At the same time, the pocket tends to change shape, sometimes leaking into the surrounding dense phase and then reforming higher up. Therefore, any argument that catalytic reactions do not take place inside the gas bubbles in a fluidized bed cannot be correct. One exception may be for very small bubbles, say about 1 mm. diam. These seemed to maintain their spheroidal shape and sharp boundaries while rising.

Particle behavior

Three kinds of phenomena were illustrated by W. H. Gauvin and S. G. Mason (*5*). The rates of fall of single solid particles (spheres, discs, cubes) in a co-current turbulent air stream were recorded with a Fastax camera at 5000 frames/sec. over a falling distance of 17.5 ft. in a 1.5-in. I.D. tube. A mirror located at one side of the tube reflected a second image, producing front and side views, on the film. This technique proved the absence of contact between the solid and the glass walls. Random rotation from 2400 to 5400 r.p.m was shown to exist in every case. The experimental drag coefficients for these large objects (about 0.3-in. across) appeared to be a function of both the rate of acceleration and the intensity of turbulence of the conveying stream.

The second set of observations concerned the orientation and pattern of movement of fibers of varying slenderness ratios suspended in a liquid moving in laminar shear flow. A detailed analysis of these results is available (*8*). A brief qualitative summary follows: A Bolex 16 mm. movie camera was used at 16 frames/sec. to photograph through a microscope, obtaining a magnification of 100X on the negative. Rigid fibers were seen to be straight and parallel to the stream lines most of the time. But at regular intervals, a rigid fiber would flip 180 degrees, remaining straight during this maneuver, and then continue its motion as before, parallel to the stream lines, but with head and tail reversed. This agrees excellently with the classical hydrodynamical theory of Jeffery (*6*). Flexible fibers behaved in a similar manner, except that they bent in several places while the head-to-tail flip occurred. Fibers of greatest flexibility were never straight; they formed helices as previously described (*3*). The head and tail of each such long fiber touched, or were very close together. The ellipse or helix rolled downstream, like a hoop with its *plane* parallel to the stream lines. It has been shown that the deformation during shear of thread-like particles has a profound effect on the viscosity of suspensions of such particles (*10*).

The third set of observations by Mason and Gauvin, based on high-speed motion pictures, showed unexpected facts concerning the coalescence of a liquid drop, initially surrounded by a second immiscible liquid phase, when the drop contacts a bulk

continued

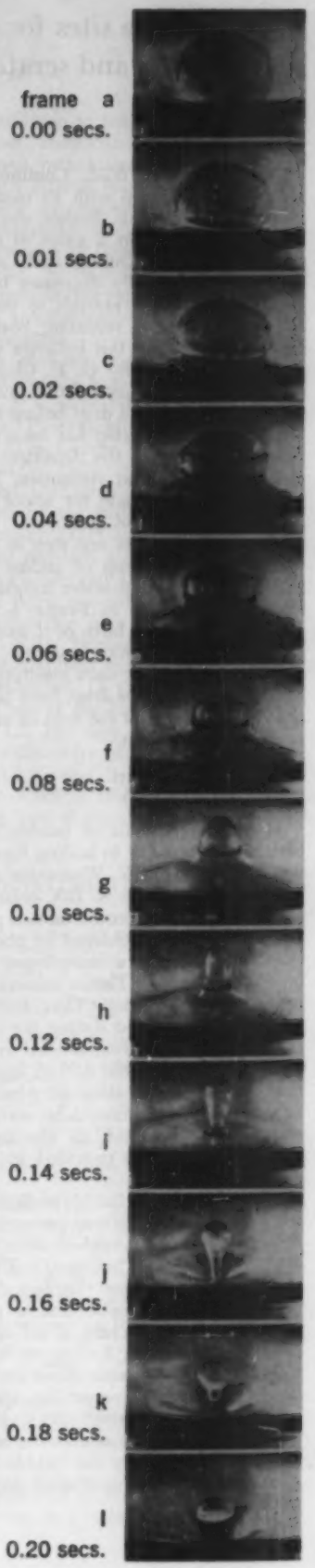

Figure 3. Stepwise Coalescence. Selected frames from a high-speed motion picture. Field of view = 0.5-in. high. An aniline drop at an aniline-water interface forms a jet which pinches off to produce a daughter drop. The daughter drop repeats the process.

. . . All active sites for bubble nucleation were found to be microscopic surface defects. Pits and scratches were the most common sites . . .

continued

of the first-phase fluid. Continuous *solution* of the drop with its mother phase does not result. Rather, the solution takes place in a series of discontinuous steps. During each step the drop size rapidly decreases to a smaller size, stable enough to stand for a time before resuming coalescence. A theory for this behavior will be published soon by G. E. Charles and S. G. Mason. A correlation giving the relative sizes of a drop before and after a coalescence step has been developed, containing the densities, interfacial tension, and viscosities. The correlation is adequate for about 20 different liquid-liquid pairs.

Figure 3 illustrates one step in the coalescence of a drop of aniline located atop an aniline-water interface. Coalescence begins in Frame *b*. In Frames *k* and *l* the birth of a second smaller daughter drop is visible. As many as seven steps, each resulting in a successively smaller drop, have been noted. The height of the field of view in Figure 3 is 0.5-in.

Bubble growth in boiling liquids

Microscopic details of bubble nucleation and growth in boiling liquids were shown by J. W. Westwater and P. H. Strenge (*13*). A 13X enlargement of the image on the motion picture negative was achieved by photographing through a metallographic microscope with a Fastax camera at near 4000 frames/sec. Thus bubble growth was observed during the few thousandths of a second needed to fill the field of view (about 0.02-in. high). Pentane and diethyl ether were boiled at atmospheric pressure on flat vertical surfaces of zinc and an aluminum alloy. A carbon arc provided illumination.

All active sites for bubble nucleation were found to be microscopic surface defects. Pits and scratches were the most common sites, but specks of foreign matter and also the boundary between the hot metal and a surrounding plastic packing gland occasionally were sites. Boiling on large single crystals of zinc gave results similar to tests on polycrystalline specimens. Crystal-face orientation was not important, and grain boundaries were of no special activity for bubble nucleation. A table of nucleation sites is available (*1*).

Figure 4. Bubble Vibrations in a boiling liquid. Successive frames from a motion picture at 1560 frames/sec. Field of view = 0.02-in. high. Pentane on a vertical zinc surface with $\Delta T = 10°F.$, heat flux = 3400 Btu./hr. sq. ft. Two bubbles coalesce to form a vibrating single bubble.

Bubble growth rates and bubble frequencies were surprisingly variable for a given set of conditions. The variability does seem to follow a normal distribution. For example, for pentane on zinc at a ΔT of 12°F, and a heat flux of 5,400 Btu./hr.sq.ft., 86 consecutive bubbles were recorded. The frequency (inverse of the time for a complete bubble growth on the surface, plus dead time after breakoff) varied from 22 to 100/sec. The mean value was 55.6, and the standard deviation was 13.6. As a first approximation, the average bubble growth rates agree with the theories of Plesset and Zwick, Forster and Zuber, and Griffith. Actually, a considerable variation was noted from bubble to bubble; more than half the bubbles grew somewhat slower than predicted. The theoretical equations are for "late" bubble growth. The fair agreement with the present observations means that the motion pictures had only recorded *late* growth. It is clear that framing speeds much greater than 4000 frames/sec. will be needed to study *early* bubble growth for the liquids used.

Numerous examples of bubble vibrations were discovered in the motion pictures. Most vibrations appeared to be of the *second order* described by Lamb (*7*). The frequencies were about 500 to 1000 c./sec. as predicted by Lamb's equations for nongrowing bubbles.

Often, the origin of bubble vibrations was the collision of two bubbles. The usual result was a sudden coalescence, with the larger bubble engulfing the smaller, resulting in rapid vibrations of the wall of the new bubble. It is possible that such vibrations influence the growth rate of bubbles and the heat transfer rate during boiling. Figure 4 shows six successive frames taken at 1560 frames/sec. In Frame 1, two successive bubbles have just nucleated at a 0.0033-in. pit (obscured by the smaller bubble) on a vertical zinc surface. In Frame 2, coalescence is imminent. In Frames 3 to 6 the merged bubble grows and vibrates.

Explosive phenomena

Framing rates as great as 1,500,000 frames/sec. were achieved by John K. Crosby and Charles H. Bagley (*2*) using a Beckman and Whitley Framing

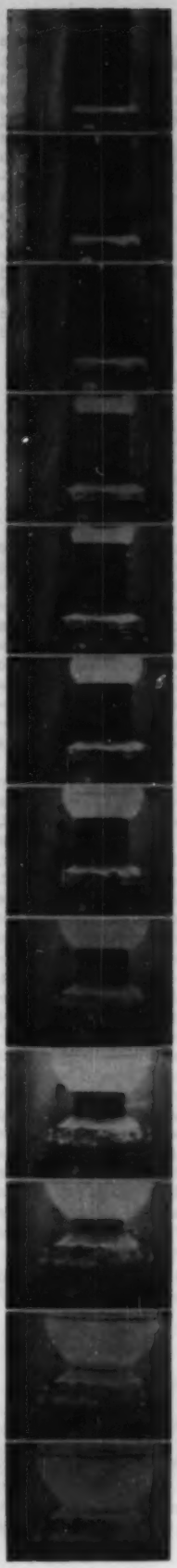

Figure 5. Collision of Two Explosions. Successive frames from a motion picture at 1,500,000 frames/sec. Field of view = 6 in. high. A solid explosive detonated at both ends.

Camera. This camera uses a spinning mirror, driven by a turbine, to sweep light from the object over a set of lenses focused on stationary film. Very great speed can be achieved, but the total number of frames is limited to 25.

The authors overcame this handicap (for purposes of demonstrating their films to the audience) in the following manner: Each frame of the original negative was repeated on 12 frames of a 16 mm. positive. Thus the projected sequences occupied enough time to permit a leisurely view.

A dozen-or-so self-luminous phenomena were demonstrated by this technique. These included: the bursting of a cylinder of explosive, the penetration of a shaped-charge jet through glass, and the interaction of shock waves from two adjacent explosions. The use of color films was shown to be of particular value for explosions. The degree of completion of the chemical reactions at various positions in the field of view can be estimated from color film, because the color of the gaseous products is a function of their composition. Color was valuable also, for proving exactly when and where liquid first escaped from a bursting container.

Additional motion pictures, taken with a framing-disc camera (built at the Poulter Laboratories) at about 5000 frames/sec. depicted the dispersion of water from a fog nozzle, the dispersion of water by a vaporizing electric wire, and several other occurrences.

Figure 5 illustrates the collision of two types of detonations in a solid cylinder of high explosive. It was photographed in color at 1,500,000 frames/sec. The detonation rising from the bottom is first visible in Frame 1; the one descending from above first appears in Frame 4. They collide in Frame 11. The field of view is 6 in. high.

Conclusions

High-speed photography is a powerful tool for studying rapid processes. In addition to the examples discussed above, chemical engineers are concerned with many phenomena about which little is known at present, and which are susceptible to attack by photography, such as: the evaporation of drops with large driving forces, the mixing of miscible liquids, phase changes during rapid melting or freezing, and the sudden growth of crystals in solution.

A growing body of literature on photography is available to the scientist. A 35-page Bibliography on High-Speed Photography has been compiled by Elsie Garvin *(4)* covering papers through 1955. Symposia on high-speed photography have been sponsored by the British Journal of Photography *(11)* and are being sponsored regularly by the Society of Motion Picture and Television Engineers. The latter symposia are international in character. The next of this series, the Fifth International High-Speed Photographic Congress will be held in Washington, D. C. in 1960.

Three of the films described herein *(2, 12, 13)* may be borrowed from the authors for use by chapters of the A.I.Ch.E. and by interested individuals. Each is 16mm. and has a running time of about 20 minutes.

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Presented at the A.I.Ch.E. Annual Meeting in Cincinnati.

* SAFETY ROUNDTABLE

the operators report on SAFETY in air and ammonia plants

*

Another CEP exclusive. Chemical engineers come together for the informal and practical discussion of safety problems in operating air and ammonia plants. Here is the actual transcript of the recent "off-the-cuff" sessions at Salt Lake City. This is Part 1. Parts 2 & 3 will appear soon in CEP.

N.H. Walton, who headed the Symposium, is general foreman in the Acid and Ammonia Group at Atlantic Refining's Philadelphia plant.

CHAIRMAN WALTON (Atlantic Refining Co., Philadelphia, Pa.): Welcome to the second annual Air and Ammonia Plant Safety Symposium of A.I.Ch.E. As you know, this is a continuation of the session held in Baltimore, which resulted from a discussion at the Boston meeting a year before that.

Air Intake

Our first topic is Air Intake. One of the principal items of interest along this line has been the development by Mine Safety Appliances of a so-called catalytic filter. Mr. R. B. Evans of that company is going to introduce the topic.

EVANS (M.S.A. Pittsburgh, Pa.): I will report briefly on catalytic oxidation as a means to remove hydrocarbons from compressor outlet air in air separation plants. In recent years, catalytic oxidation or "filtering" in this field has been closely associated with the word "Hopcalite." This is a trademarked name for any MSA catalyst containing manganese dioxide and cupric oxide. These catalysts are important for hydrocarbon oxidation because they operate at low temperatures. For example, butene is completely removed at a temperature as low at 235°, acetylene at 325°, propylene at 335°, ethylene at 375°, butane at 470° and propane at 500°. These are minimum stream temperatures for 100% oxidation for a contact time of only 0.2 second. The operating temperature can be reduced if the contact time is increased, but it is necessary to balance economy, pressure drop and size of the installation. A 0.2 second contact selection seems rather critical in this respect. The operating temperature requirement comes down very slowly from here on with increasing contact time. For example, to reduce the operating temperature on acetylene by 30°F., it is necessary to increase the contact time to 0.3 second. That's a 10% reduction in operating temperature and and a 50% increase in contact time, and you can readily see what that will do to either the size or pressure drop of the installation.

In 1956, L'Air Liquide suggested to MSA that "Hopcalite" filters might find application in air separation plants—and they had some data to support this contention. During 1957, two installations were made— a 45,000 std. cu. ft./min. bank at Rohm & Haas in Houston, Texas, and a smaller bank at Petroleum Chemicals, Inc. at Lake Charles, La. The former has been in operation for more than a year, and, to date, the operator has never had any evidence of acetylene downstream of the filters. They sample both from the air stream and the liquid pool with, among other things, infra-red instrumentation with a full-scale range of from zero to 2 pts./million acetylene. Traces of other hydrocarbons such as ethylene have been detected, but this is to be expected because the operating temperature at the catalytic bed in this plant is only 315°F. If elevated to 375°F., all of the unsaturated hydrocarbons should disappear. The system was set up to have an initial pressure drop of ¾ lb./sq. in. The mechanical prefilters, which are necessary to any catalytic installation, were to be changed when the pressure drop reached 1½ to 2 lb./sq. in. ga. I understand that the pressure drop has now reached about 8

R.B. Evans, who reported on catalytic oxidation, works on fluid purification equipment at Mine Safety Appliances Co.

lbs./sq. in., but no filter changes have been made in over a year of continuous compressor operation. They evidently do not need the full oxygen capacity at the moment. The second installation is in operation but we do not have a full report on its performance. MSA has also prepared two small sample cells for tests at the Dow Chemical Company at Freeport, and for the Atlantic Refining Company at Marcus Hook, but these results have not been reported.

MSA's development program has been aimed along two avenues; (1) to reduce the operating temperature of the catalyst, and (2) to reduce the pressure drop or the space requirement. In the former, there is nothing encouraging to report. We found many accelerators to reduce the required operating temperature for specific hydrocarbons, but none of them worked over the wide range of hydrocarbons you must consider. For example, we have one catalyst which will completely oxidize methane at 600°F., but this same catalyst requires 400°F. to oxidize acetylene; considerably higher than the "Hopcalite" now in use. The second avenue toward improvement has been more productive and we hope soon to have a few low-pressure-drop catalytic filter assemblies on the market. These are to operate at a few inches of water resistance rather than ¾ lb./sq. in. in our present system. We certainly hope to be able to show new elements to you by the time of your next meeting.

CHAIRMAN WALTON: Thank you very much, Mr. Evans. Any comments?

R.L. Swope, treasurer and chief engineer at Southern Oxygen Co, in Washington, D.C.

SWOPE, Southern Oxygen, Washington, D. C. I'd like to know whether any

attempt to use this catalyst in a high-pressure air stream has been undertaken to date?

EVANS, M.S.A.: None to date, Mr. Swope. The problem there is the oil from reciprocating-type compressors. That has yet to be overcome before an installation of this type can be made.

SWOPE, Southern Oxygen: This then is particularly applicable to centrifugal air compressors. Is that correct?

EVANS, M.S.A.: Yes.

GRUNBERG, L'Air Liquide, Montreal, Canada: In the Rohm & Haas plant, which is a 350-ton plant, the conditions are especially favorable because it has a blower. The air is compressed to approximately 92 lbs./sq. in., and at the outlet of the compressor—before it is cooled down in the spray-tower—the air goes through the MSA unit. We have been satisfied with the low pressure drop obtained with the MSA unit. The problem of purifying a gas which has been going through an oil lubricated compressor is a bit tricky because here we are dealing with small amounts of oil vapor which in going through these units may be oxidized to a fair amount of CO_2 and this has to be removed by some other means. In a high-pressure plant the CO_2 can be removed by cooling. The general practice is to decarbonate at

J. F. Grunberg, manager process development at L'Air Liquide, Montreal, Canada.

about 400 lbs./sq. in. By high-pressure plants, I mean liquid plants with air at approximately 2900 lbs./sq. in., so the decarbonation units operating at 400 lbs. allow removal of the oil with the condensing water vapor which acts as a good scrubber. A special heating device has to be added to the MSA unit. These units at the Rohm & Haas plant operate at approximately 300°F., which is a good discharge temperature for a blower, although a slightly lower temperature would be desired where energy is costly. I think if we could operate these units at 270°F., it would allow us to use compressors with efficiency improved by inter-stage cooling. Even if a small amount of heat had to be supplied to the catalytic unit it would not be too costly.

We consider that the oxidation of acetylene in the air before it enters the low temperature separation plant is the best way to have a safe plant, because the remedy is taken at the source before the hydrocarbons enter the plant. If any unknown gas contaminant is, after compression, brought into contact with a finely divided catalyst, there is a better chance to avoid unknown reasons of explosion within the plant. The use of catalytic oxidation of acetylene does not, however, eliminate the use of liquid filters, which will be mentioned later.

G.R. Walton Jr. is with the Houston, Texas, plant of Rohm & Haas as production area manager.

WALTON, Rohm & Haas, Pasadena, Texas: I do want to substantiate Mr. Evans' remarks. The only problem we have had to date is the developing of a high pressure drop (8 to 10 lb./sq. in.) across the filter after about six months operation. Unfortunately, we did not provide a bypass around the filter, thus the exact cause of the pressure drop cannot be determined until a future shutdown.

CHAIRMAN WALTON: At Atlantic, as mentioned by Mr. Evans, we have a sample cell which contains one filter element with which we are checking performance in order to justify full scale installation.

H.R. Lyles of Petroleum Chemicals at Lake Charles, La, is a process superintendent in the oxide glycol unit.

LYLES, Petroleum Chemicals, Lake Charles, La.: Is there any experience with the effect of trace sulfur compounds on this MSA catalyst, particularly hydrogen sulfide?

EVANS, M.S.A.: The sulfur compounds will destroy any catalytic surface if they are deposited as free sulfur or salts. So long as you operate the system at a temperature low enough there is no effect on the catalyst.

CHAIRMAN WALTON: Thank you. Any other questions or comments?

FUNK, German Linde, Toronto, Ont.: We have been experimenting with a pilot plant to burn hydrocarbons in air. The type of catalyst we have chosen was in use for the combustion of methane in oxygen-krypton mixtures at a temperature of about 750°F. The objective is to purify this stream to a few parts/million of methane. This contact material contains no precious metals. A temperature of 480°F is sufficient. At 85 lb./sq. in. ga., with space velocities of 3000-5000 cu. ft./hr. per cu. ft. of catalyst, and with 10 - 60 parts/million of hydrocarbons in moist air, there were burned:

98% of total	C_2H_2
99%	C_2H_4
91%	C_2H_6
75%	C_3H_8

Fortunately, acetylene burns very easily and completely. Likewise, as with precious metal catalysts, humidity in air decreases efficiency of oxidation. Saturated hydrocarbons burn less easily than olefines. The temperature of the catalyst bed is mainly determined on the basis of whether saturated hydrocarbons like propane, ethane, or olefines and acetylene are to be removed. Normally, it is not necessary to remove methane at all. The presence of substances which shorten the life of precious metal catalysts has not influenced the catalyst-life during our experiments. Actually, a catalyst of this type has been in operation for several years.

To keep the heat exchange surface small enough for heating from 212 to 480°F, and cooling down from 480 to 212°, and then respectively to 68°, and also to minimize the costs, a gas-fired air heater is provided which operates on high

H.F. Funk reported on a pilot plant to burn hydrocarbons in air at German Linde Corp. in Montreal.

temperature differential and, therefore, with a small exchange surface. A steam boiler is used for cooling the first stage. The steam boiler also has a high transfer coefficient, and, hence, a relatively small heat exchange surface. Regenerators used as heat exchangers would need a heat exchange surface many times the area, resulting in higher costs. About eight cubic feet of methane will have to be burned with 1000 cubic feet of air, and a considerable amount of heating value can be recovered as steam at about 43 lb./sq. in ga. In this way we hope to have an approach for an economical method of burning hydrocarbons in the air inlet before entering the cold box.

CHAIRMAN WALTON: How about lubricating oil? Is it a problem with your catalyst?

FUNK, German Linde: In the large plants we are concerned only with non-lubricated turbo-compressors. Oil vapors are, however, burned in the catalyst bed.

CHAIRMAN WALTON: This seems to be one of the problems still with the MSA unit. Mr. Evans?

EVANS, M.S.A.: There may be a misunderstanding. It is not that the catalyst is destroyed by the oil, it is just that there's a possibility that there will be too much fuel applied to the bed instantaneously. Under these circumstances, the temperature in the bed would rise to a point where the catalyst would be sintered.

Solids in intake air

GRUNBERG, L'Air Liquide: I would like to come back to this question of pressure drop on the MSA catalyst. We are not too concerned about it. At our suggestion, MSA built for Rohm & Haas a unit which purifies 33,000 std. cu. ft./

Continued

Continued

min. of air. Of course, the origin of the increasing pressure drop will have to be investigated during the next shut down. It is possible that the pressure drop comes from some minute amount of solids deposited on the bed.

(*Mr. Grunberg has later advised that during the January 1959 shutdown the increased pressure drop has been found to be caused by the deposit of iron oxide on the catalyst containers.*—EDITOR)

CHAIRMAN WALTON: The next subtopic is the necessity for removal of particulate matter. This has been a matter of concern to some of us, who wonder about whether our air tower trays are, in a matter of time, going to fill up with dirt. We, at Atlantic, made a dust survey, and I'd just like to mention the figures which we obtained. This was about six months ago. We found that in our air intake to the compressor we varied between 18 and 16 lbs. of dust per billion cu. ft. The effectiveness of the wetted leaf filter was such that we had 1 to 4 lbs./billion cu. ft. going to the reversing exchangers. In our plant it takes about 3 months to process a billion cu. ft. In the air distillation tower we found 0.75 to 3 lbs. of dust per billion cu. ft. This dust actually passed through the reversing exchangers—we have actually found dust when we have opened the lines. From the reversing exchangers to waste air, we found 0.25 to 1 lbs./billion cu. ft. of dirt. In the nitrogen we found 0.2 lb. per billion cu. ft. In the blowdown the amount was extremely variable. It cycled up and down as the cycling took place in the intake air. This study was made with the High-Volume Air Sampler, available from General Metal Works, Cleveland, Ohio. The MSA filter also takes out particulate matter. That's one of its advantages.

G.U. Weigers, is in the Oxygen Department of American Cyanamid's New Orleans Plant.

WEIGERS, American Cyanamid, New Orleans, La.: Have you had the opportunity to open your column and find out whether this particulate matter was depositing on the trays?

CHAIRMAN WALTON: No, we haven't, but we have done this in the past. We did take out the internal thermowell in the re-boiler, and saw a very light deposit of dust on the re-boiler tubes.

WEIGERS, Cyanamid: We opened up one of our low-pressure columns last month, and, to our surprise, found no evidence of particulate matter on the trays after 4½ years of operation. We're sure that some particulate matter is getting through our filters, but we have had no evidence of a build up in any particular part of the plant.

CHAIRMAN WALTON: That's an interesting observation.

LAWRENCE, U. S. Industrial Chemicals, Tuscola, Ill.: Mr. Walton, did you analyze the dust?

CHAIRMAN WALTON: Yes. We have, very close to our ammonia plant, a waste water plant. All the waste water from the refinery goes through there, and solids are filtered out and burned in an incinerator. The dust was found to be fly ash from that incinerator.

J.A. Lawrence is superintendent of the Ammonia Plant of U.S. Industrial Chemicals at Tuscola, Ill.

LAWRENCE, USI: We probably have more solids due to corrosion in our suction line. We've analyzed them and found they're mostly iron sulfate. We found it in our exchangers when we derimed. It gets stuck in the ice in the exchangers. We don't have reversing exchangers. I was wondering, would MSA's filter be ruined if one didn't use a pre-filter? Also, would a filter be improved with tri-cresyl phosphate in it, or is this material considered a hazard in an air plant?

CHAIRMAN WALTON: I can say that we have a wetted leaf filter which uses tri-cresyl phosphate, and so far we do not believe that to be a hazard. We're not really sure of that.

F. Himmelberger is safety director at Air Products, Allentown, Pa.

HIMMELBERGER, Air Products, Allentown, Pa.: I have a brief comment on tri-cresyl phosphate. We have taken a number of the phosphate ester-type lubricants, slurried them in liquid oxygen, and ignited them either with a flash bulb or a small blasting cap. We were always able to produce explosions when the stronger source of initiation was applied.

CHAIRMAN WALTON: There is a pre-filter which is designed to remove particulate matter before the Hopcalite section in the MSA filter. Isn't that correct, Mr. Evans?

EVANS, M.S.A.: That is correct, it is an extremely efficient "ultra filter" which will take out all particulate matter with efficiency in the order of 100% down to 3/10 of a micron. Obviously, you should not expose this type of filter to particulate of 10 microns or larger in size; you would just waste its usefulness.

ROTZLER, Monsanto Chemical, Texas City, Texas: At the meeting last year I described an explosion which occurred about three years ago in a reboiler in our plant. I raised a question which existed in our mind as to whether soot, which we know to be present in the air around our plant in rather small but very definite quantities, might cause an explosion; therefore, whether the removal of this particular kind of particulate matter might be a special problem in oxygen plants. Work since that time has indicated that although it is certainly possible to get detonations between finely divided carbon (soot) and liquid oxygen, the conditions are somewhat special. Not every mixture of liquid oxygen and carbon will produce a detonation, nor are these mixtures easily detonated; it takes a considerable amount of energy. So while I don't think soot can be ruled out as a safety problem in oxygen plants, as a progress report let me say that we do not feel it was the cause of our explosion.

R. W. Rotzler, manufacturing superintendent in the Plastics Division at Monsanto's Texas City, Texas, plant.

CHAIRMAN WALTON: Thank you. It's good to tie in some of these things which were discussed last year and left open.

KNAPP, American Messer, New York, N. Y.: I would like to make one more remark regarding gas removal. In our regenerator plants we use a system for cooling the air working on the following principle. There are two towers. In one, water is contacted with the effluent nitrogen and cooled down by heat exchange and by evaporation of water into the dry nitrogen coming from the plant. In the second tower the incoming air is cooled and scrubbed with this water, after having passed the aftercooler of the turbo compressor. We found that this water scrubber serves very effectively in removing dust from the incoming air before the air enters the low temperature plant.

H. Knapp, process engineer at American Messer Corp, New York City.

Air compressors

CHAIRMAN WALTON: Air compres-pressors have been a problem for many years, and one which is not entirely solved as yet by any means. Mr. W. F. Cummings of Shell Chemical has consented to introduce this topic.

CUMMINGS, Shell Chemical, Pittsburg, Calif.: Fires originating from deposits of carbonaceous materials in air

compressors and auxiliary piping, surge vessels, and inter-coolers are a serious industry-wide hazard. This topic is included on the agenda to highlight the potential hazard present wherever air compressors are operated.

The fuel for these fires or explosions is usually the lubricating oil and the carbonaceous products formed by oxidation of this oil. Many theories have been advanced concerning the mechanism of initiation. A few of these are: (1) ignition of deposits by glowing carbon blown

W.F. Cummings, manager of Shell Chemicals Operations Department at Pittsburgh, California.

from the cylinder area; (2) auto-ignition of oil vapor-air mixtures; (3) formation of organic peroxides with the lubricating oil leading to further exothermic oxidation reactions; (4) auto-ignition of carbonaceous deposits by the exothermic reaction which occurs during formation of a carbon-oxygen complex when oxygen is absorbed into the deposit, as theorized by investigators of the Bureau of Mines. On application of above-normal temperatures, and we feel that somewhere in the neighborhood of 300°F, this complex breaks down into CO_2 and CO. If the net heat generated is not removed, spontaneous ignition may result.

Regardless of which mechanism actually causes ignition, a high operating temperature is the common factor in all the theories. This high temperature may result from one or more of the following conditions: (1) broken, dirty or leaking valves; (2) leaking piston rings; (3) insufficient jacket cooling or interstage cooling. However, under certain conditions, excessive cooling could cause condensation which will destroy your lubricant and result in scuffing and high local heat. A hot piston might then result. (4) Unusually high compression ratios.

Suggested methods to minimize likelihood of fires

Certain metals act as catalysts in the oxidation of oil, of which bronze and many other copper-containing alloys appear to be the most active. We have found that pistons and rider rings constructed of non-copper materials, such as molybdenum disulfide impregnated bakelite, should be used. When designing your compressor auxiliaries, it has been our experience that piping runs should be as short as possible, especially where high temperatures might be encountered, such as between the compressor stage discharge and your coolers. Also, locations where carbonaceous materials might collect, such as baffles and excessively large surge vessels, should be minimized.

The formation of carbonaceous deposits in air compressors depends on the type and the amount of lubricating oil used. It is essential that the minimum quantity necessary to provide lubrication be determined. Any excesses will promote carbon deposition. Numerous non-combustible compressor lubricants which have been recommended for use in air compressors are on the market. The majority of these lubricants are phosphate esters which provide good flow, high glow and wetability characteristics with a subsequent low carbon formation.

High temperature alarms may be installed on the discharge of each compressor stage if sufficient operator supervision is not available. However, it must be pointed out that the reliability of these alarms is questionable in the event the thermowells become insulated by carbon deposits. Another detector is the barium hydroxide bubbler. Based on a theory by the Bureau of Mines, formation of CO_2 is indicative that conditions necessary to cause a fire have developed. Installation of a barium hydroxide bubbler on a side stream from your compressor discharge should provide warning of this CO_2 formation.

Carbonaceous deposits should be cleaned from air compressors, auxiliary piping, and intercoolers, at frequent intervals to avoid excessive buildup. A six month timing is suggested.

Here, in summary, are some useful rules for the operation of air compressors. (1) Take the inlet air from a cool, clean location. Use an adequate air filter and service it regularly. (2) Use adequate intercoolers. Maintain jacket and interstage suction temperatures low, but never below the dew point of the gas for the discharge pressure involved. A good rule here is never to let the incoming gas be above the temperature of the water jackets. The number of stages selected should provide moderate compression ratios for each stage. (3) Maintain clean intercoolers and jackets. Inspect discharge piping, reservoirs, cylinders, etc. regularly. Clean as required. Provide sufficient clean-outs and drain valves. (4) Check operation of valves frequently. Repair as soon as they are found faulty. (5) Use the least amount of a good, inhibited oil that will lubricate the cylinders satisfactorily, and. (6) clean air compressors with soap solution rather than with inflammable or volatile substance. Provision should also be included that, in event of fire, the location may be purged with nitrogen or flooded with water.

CHAIRMAN WALTON: There's a great deal of interest in Teflon rings. I know in one instance of their use with reduced lubrication. Is there anybody who would like to comment on experience with Teflon rings with no lubrication at all?

W.A. Mason, group leader with Dow Chemical's Process Engineering Department, Midland, Michigan.

MASON, Dow Chemical, Midland, Mich.: We have tried Teflon piston rings

* SAFETY ROUNDTABLE

in circulating pumps operating at 5000 lbs. pressure at Midland. Garlock Rockhard Piston Rings have been used previously with lubrication. These rings operated satisfactorily for three months before removal for examination. They were satisfactory except for severe wear at a point where the cylinder had previously been badly scored. This does not necessarily mean that Teflon piston rings would be perfectly satisfactory for use in a new cylinder liner. This particular application gave the piston rings every opportunity because the cylinder had been previously polished to a mirror finish by the lubricated Rockhard Piston Rings. This trial looks promising. As to the source of these Teflon piston rings, they were purchased from Koppers Company, Inc., Baltimore, Maryland.

CHAIRMAN WALTON: France Packing Company I know, also makes Teflon rings.

SWOPE, Southern Oxygen: We're using Teflon rings in an expander operating at about —100 to —150°C with no lubrication. This set has been in operation for about a year and is working satisfactorily. A previous set of rings wore out in about 30-45 days, as we were warned in advance. Apparently there is some polishing of the cylinder walls which takes place.

CHAIRMAN WALTON: I think Teflon offers one of the greatest possibilities in this problem of getting rid of the lubricant entirely. Ingersoll-Rand is working on a proposal for our particular installation, for changing over to Teflon rings. I think there are two types. One is a glass fiber strengthened Teflon, and the other is copper. Mr. Swope, which were yours, do you know?

SWOPE, Southern Oxygen: I would say they may have been glass fiber. I don't recall any copper. The rings are backed by a stainless expander spring.

FUNK, German Linde: We have so-called labyrinth compressors which do not use lubrication at all. They run on so-called labyrinth seals.

Referring to explosions or fires in air compressors, I would like to say that we once experienced a fire in an air compressor and traced the cause to carry-over from the caustic wash tower between the second and the third stage of compression. This explosion occurred in the third stage. Apparently the caustic lye had deteriorated the lubricating oils in the cylinder, then carbon had deposited on the third stage cooler and autoignition set off the detonation. Therefore, a carry-over of lye should be prevented.

PUTMAN, Superior Air Products, Newark, N. J.: We have also used Koppers glass-Teflon rings in a low tem-

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perature expansion engine and discovered that the first set of rings apparently wear in to the cylinder's surface and then you get a service life on the second set of rings ranging anywhere from 5,000 to 7,000 hours. These rings are used at low pressure ranges, expanding from 600 to 60 lbs./sq. in.

L.E. Putnam, chief engineer at Superior Air Products, Newark, N.J.

CHAIRMAN WALTON: Those of us who have to use oil lubricated compressors, either air compressors or others, have some concern about oil removal devices, and I'd like to report on our experience. We have tried silica gel, F-1 alumina, H-151 alumina, cotton batting and felt. The silica gel and also the F-1 alumina have given us trouble with powdering so we ruled those out. The H-151 has not powdered, but it leaves something to be desired on oil removal. We recently had a visitor from the government helium plant at Amarillo, and he spoke about the use of cotton batting and felt as being one of the most effective means. We have just installed several layers of felt and cotton batting and we don't have anything to report on it as yet. Does anybody have any comments on oil removal devices, down to the last trace?

EVANS, MSA: We have just recently developed a filter for the Kinney vacuum pump effluent, and it removes particulate matter down to 3/10 micron size at high efficiency. This filter handles 150 std. cu. ft./min. It is about 10 inches in diameter and perhaps 20 inches high. It picks up about 10 lbs. of oil, oil mist or fog (very finely divided particulate which appears as smoke if it is left free in the atmosphere) every 4 days, then the element is cleaned by soaking overnight in naphtha. To date we have not established how many cleanings can be repeated, but we know it is more than ten.

CHAIRMAN WALTON: Any other comments?

D.L. Stockbridge, Jr., of Southern Nitrogen, Savannah, Georgia.

STOCKBRIDGE, Southern Nitrogen Co., Savannah, Ga.: We had some problems with oil in our instrument air. We thought we had it licked when we used a cresyl lubricant, but we found that this carried into our instruments. Many of these have neoprene bellows and the lubricant deteriorated those to such an extent that we had to discontinue the use of the so-called non-flammable lubricants.

We have been using wool felt in our filters for about six months, and it seems satisfactory.

FAATZ, Foster Wheeler, New York, N. Y.: Our early experience with removal of oil from air streams indicated that two problems are involved, and they have to be considered separately. One is the removal of oil fog, and the other is removal of oil vapor. In the first plant we built we used an alumina adsorber and the fog tended to go through it. It was necessary to agglomerate the fog with a felt filter before passing the vapor into the alumina or charcoal bed for adsorption. The idea is to prevent the vapor from condensing on cold surfaces of subsequent equipment.

GRUNBERG, L'Air Liquide: We have found it advantageous to cool the air down to around 40°F before removing the last traces of oil vapor. At 40°F, a substantial amount of water is simultaneously condensed, which seems to facilitate oil removal.

R. F. Bollen is Ammonia plant Supervisor for Dow Chemical Ltd. at Sarnia, Ontario.

BOLLEN, Dow Chemical of Canada, Sarnia, Ont.: We had quite a problem with the excessive amount of oil in the high-pressure nitrogen stream to our nitrogen scrubbing unit. Our installation had a felt pad filter and we tried increasing its efficiency by installing special knock-out pots, without success. Since that time, we have installed an activated carbon (10-20 mesh) filter ahead of the felt pad filter, and now find very little oil on the felt pads. We are hoping this will extend the operating period of our cold box. We have also installed an ammonia refrigerated pre-cooler (to —10°F.) on the high-pressure nitrogen stream ahead of the carbon filter.

ANONYMOUS: The activated charcoal —what grade is it?

FUNK, German Linde: It is a little difficult to remove oil vapors from dry gas. For that reason, we inject steam and under these circumstances it is very easy to remove oil.

Silica gel adsorbers

CHAIRMAN WALTON: The next topic on the agenda is silica gel adsorbers. This has been fairly well covered in papers which have been published in *Chemical Engineering Progress* and discussed at Baltimore. We are particularly interested at this time in anything new in experience or thoughts which have come up in the past year. Are there new developments on service life, difficulty with powdering, regeneration temperature, or testing to determine how critical the regeneration time is and what is the optimum time temperature for regeneration? Dr. Grunberg of L'Air Liquide is going to introduce this topic.

GRUNBERG, L'Air Liquide: Whatever are the means for removing hydrocarbons ahead of the plants as with catalytic units, it is always necessary to use liquid filters. At the present time no air separation plant is built without liquid filters or cold filters. The main purpose of these filters is to remove acetylene, which has a very low vapor pressure at the temperature of liquid air and oxygen. Its solubility at the temperature of boiling oxygen does not exceed 5 to 6 parts/million. The maximum concentration which is generally considered as safe in the air to be treated is 1 part/million. However, this concentration is at times often exceeded. Provided higher concentrations of acetylene in the air do not last too long, the filters can usually take care of them, but is not a very safe type of operation. Liquid filters should be preferably used on the whole stream of air or rich liquid treated.

Various types of adsorbents are being used in these filters, and it appears that the best one is "SOVABEAD" mainly because the loss by attrition is negligible. Plain silica gel has a tendency to powder, and is more sensitive to temperature changes. The basis of design is of the order of magnitude of 600 lbs. of adsorbent per vessel and for 100 tons/day of oxygen produced. This amount is sufficent to take care of 1 part/million of acetylene for a period of approximately 7 days. An important factor in the operation of these filters is the temperature at which they are regenerated. It appears that the temperature of 250°F. is optimum. The SOVABEADS can withstand temperature as high as 450°. It is preferable to leave no trace of water and heavy hydrocarbons on the beds after regeneration.

These filters do not adsorb methane in appreciable amounts, but do adsorb some higher components. Another type of filter has been introduced in some plants. It is a cold filter in the gas phase. It seems to effectively adsorb some high boiling components like butane and propane at low concentrations.

If gas phase adsorbers are used, very good screens must be installed in order to stop the micron-size particles produced by attrition. These would be detrimental in the operation of high speed turbines.

MASON, Dow: One of the items on the agenda included measuring the amount of material adsorbed on the gel. When our air separation plant at Midland was started, we regenerated the adsorbers every day. We also determined the amount of adsorbed material, and the concentration of hydrocarbons in the liquid oxygen, every day. After six or eight weeks of operation, our data convinced us that we should regenerate the adsorbers only twice per week, and determine the total hydrocarbons desorbed from the adsorbers only once per week.

The procedure for determining total hydrocarbons desorbed from the adsorbers consists of several steps. During the entire regeneration process, the effluent nitrogen from the adsorber is

divided into two parts. The major part of this effluent is metered and vented to the atmosphere. A small but constant proportion of the effluent is passed through a trap, cooled to liquid nitrogen temperatures to condense any hydrocarbons and CO_2. It is metered with a wet test meter. After the regeneration period is completed, the trap is warmed and the condensed hydrocarbon and CO_2 is transferred to an evacuated volumetric flask by flushing with dry nitrogen. The mass spectrometry department then analyzes the sample and reports its composition and standard volume at 0°C. and 760 mm. of mercury. With the composition and standard volume of the sample, and the metered volume of the total nitrogen used for regeneration, we calculate the total amount of each constituent that has been desorbed in the complete cycle.

On the basis of these examinations, we believe we are operating with a factor of safety of 10. That is, the adsorbers have a capacity of about 10 times as much as has accumulated during our worst cycle. This might be of interest to some others who would like to make such determinations.

CHAIRMAN WALTON: We use silver sova in our silica gel adsorbers and after three years, when we had a shutdown, we changed it because we thought it might be a good idea to see what it looked like. There was very little powdering and very little change in color. Examination in the laboratory indicated that it was about as effective as it had been when it was new.

WEIGERS, Cyanamid: My question concerns the useful life of the silica gel adsorbents. We too have changed the silica gel in our gas phase as well as our liquid phase adsorbers after three years of plant operation. The initial layers of gel (perhaps 6 inches to 12 inches in depth) in both the adsorbers were discolored. The top layers were quite dark brown. Going down in the bed this brown color got progressively lighter, and even after the brown had disappeared, the silica gel, instead of being a semi-transparent crystal, was opaque milk white. An analysis of this discolored gel indicated something like 0.3 percent hydrocarbon by weight. However, we did not characterize the hydrocarbons. We have decided to change the new gel after a two year run. I'm curious as to whether any of you have experienced similar hydrocarbon contamination of the gel, and if you have, what is your program for changing gel?

MASON, Dow: At Dow in Midland we, too, have found discoloration of the silica gel on the top of the bed. Our Spectroscopy Department reported that the discoloration was caused by a small amount of carbonization. However, there was no appreciable effect on the adsorption capacity of the gel.

COCHRANE, Sun Oil, Philadelphia, Pa.: We have two sets of silica gel adsorbers. One set is on the stream between our low pressure column and our reboiler condenser, and has been in service about 20 months. We have periodically checked the efficiency of these adsorbers for removing all C_4 and heavier hydrocarbons, mostly saturates. We have found that in a period of about a year, the adsorption efficiency has remained about the same. We plan to change the gel after possibly a three year run.

WRIGHT, Standard Oil Co. Whiting, Ind.: I wonder if anyone was working on adsorbent filters for removing ethane and methane from the rich liquid stream?

HIMMELBERGER, Air Products: As to adsorption of ethane on silica gel, Dr. McKinley and Dr. Hsu of our laboratory are running extensive tests on adsorption, and they will be prepared to present a paper on the subject entitled "Adsorptive Purification of Liquid Oxygen" at the AIChE meeting in Cincinnati in December, 1958. (*Shortly to be published in CEP . . . Editor*)

CHAIRMAN WALTON: Any other comments on gels?

KNOX, St. Paul Ammonia Products, South St. Paul, Minn.: It appears to me the real problem is whether you have had any indication of reaching a breakthrough point in your filters. On your three-year basis, did the actual operating levels of hydrocarbons in your low pressure column show any tendency of rising?

CHAIRMAN WALTON: In our case, no! We didn't feel that we were anywhere near the point where we had to even change our regeneration or our 7-day onstream time.

WEIGERS, Cyanamid: We found exactly the same thing as far as the adsorptive capacity of the gel was concerned.

STEVENS, Phillips Petroleum, Idaho Falls, Idaho: I'd like to tell you about some of our lab experiences with silica gel as an adsorbent for radioactive nuclides, specifically ruthenium tetroxide, from an air stream. These, of course, can be analyzed for in very low concentrations. We are testing silica gel at a moderate temperature, with large amounts of nitrogen oxides and water vapor present.

J. I. Stevens, is with Phillips Petroleum as Group Leader for Process Design in the Atomic Energy Division.

We found that after the silica gel had been saturated, after perhaps 20 times the saturation volume of water had passed through the beds, it still has an affinity for adsorbing the ruthenium tetroxide. However, the over-all efficiency while good (decontamination factor of perhaps 1000) still gives us a tailing-off curve, even though we are having these very high decontamination factors. I'm sure that you aren't going to be concerned with the same problems as I. However, what is your experience in regeneration?

* SAFETY ROUNDTABLE

How many cycles have you gone through before you had excessive pressure drops, etc., during the regeneration of silica gel beds?

CHAIRMAN WALTON: We in this three-year period regenerated each gel case once a week and we had no indication of increased pressure drop during that three year period.

Reboilers (or vaporizers)

The next topic is reboilers or vaporizers, which will be introduced by Mr. Himmelberger.

HIMMELBERGER, Air Products: What we've heard up to now deals with keeping things out of air plants. Now let's consider the traces that get in. We'll discuss:

1. The kind of hazard which can occur in the reboiler.
2. How the hazard can be defined during plant operation.
3. How it can be measured quantitatively.
4. How it can be eliminated.

Most of the larger air separation plants in the chemical industry today employ a double column. An integral component of the cycle is a reboiler-condenser, which condenses nitrogen to provide reflux to both the columns. Refrigeration for this is obtained by vaporizing liquid oxygen. Heat exchange surface is generally provided by a tube-in-shell type reboiler-condenser, in which low-pressure oxygen boils vigorously. Much of the liquid oxygen entering the reboiler leaves in the vapor phase. In spite of judicious location of air intakes and careful operation of air purifying units, minute traces of impurities may reach the reboiler. Since boiling takes place near —300°F., most of the impurities will have extremely low vapor pressures, causing them to concentrate in the liquid fraction. If no liquid is withdrawn from the oxygen side of the reboiler, the concentration of impurities depends upon the inlet composition, vapor pressure of the contaminants, and time. Hazards arise when contaminants reach their lower limit of flammability or exceed their solubility in the liquid oxygen. Maintaining the concentration below the solubility level is important for two reasons:

1. Explosive local concentrations, even though average impurity levels are below the flammable limit.

2. Splashing of undissolved particles onto the cold walls above the liquid level, forming a combustible interface with the oxygen vapor.

Knowing what impurities to expect, accurate data on solubilities and flammable limits can help to establish safe operating conditions.

Fortunately, gas phase lower com-

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bustible limits are well known; extensive publication in this field has been sponsored by the U. S. Bureau of Mines. Their bulletin 503, *Limits of Flammability of Gases and Vapors*, by Coward and Jones, is a valuable reference for air plant operators. The book by Lewis and von Elbe, *Combustion, Flames and Explosions of Gases*, is of interest to those curious about the underlying theory of combustion. Although the data on flammable limits of combustibles in air are more complete than those in oxygen, it will be noted that where both have been investigated, the lower flammable limits in air and gaseous oxygen are almost identical, and so it is safe to generalize on this. The next comparison necessary is the relationship of gas phase lower combustible limits with those in the liquid phase. To sustain flame, energy produced by the reacting gases must be sufficient to excite the unreacted portion to flame activity. To meet this requirement in low-temperature liquids, more energy, hence more fuel, is needed and the lower limit can be predicted as being higher than that of the gas phase limit. Experimentation in our laboratory indicates this to be true for methane, ethane and propane.

Another experimental finding, useful in air plant safety work, is that mixtures of soluble hydrocarbons in liquid oxygen did not explode when their C_1 or equivalent carbon atom concentration was maintained below 5 percent.

Figure 1 depicts flammability limits of the system, methane-oxygen-nitrogen. Any mixture within the hatched area is flammable in the gas phase; flammable liquid compositions are contained in the envelope within the dotted line. For rough estimation these values may also be considered to apply to other soluble hydrocarbons, providing concentrations are expressed in terms of equivalent carbon atom percent, rather than mole percent. A composition as pictured at "A" is safe; a composition at "B" is capable of ignition.

Another aspect demonstrated by our laboratory explosion studies was that explosions were readily initiated below the gas phase limits in ethylene, acetylene, and other hydrocarbon mixtures with liquid oxygen when their solubilities were exceeded. Formulation of safe limits, then, requires accurate knowledge of solubilities. To supplement rather meager published data prior to 1956, our laboratory initiated a program to investigate the solubilities of hydrocarbons and other substances in liquid oxygen. Some early results were published in an article on "Oxygen Plant Safety Principles" in the March 1957 issue of *Chemical Engineering Progress*. At the Cryogenic Engineering Conference in Cambridge, Massachusetts, in September 1958, a more complete discussion of solubilities and their determination was presented in a paper by Dr. McKinley and Mr. Wang of our laboratory staff. Figure 2 is a plot of some of the data as solubility vs. temperature for saturated hydrocarbons. Note

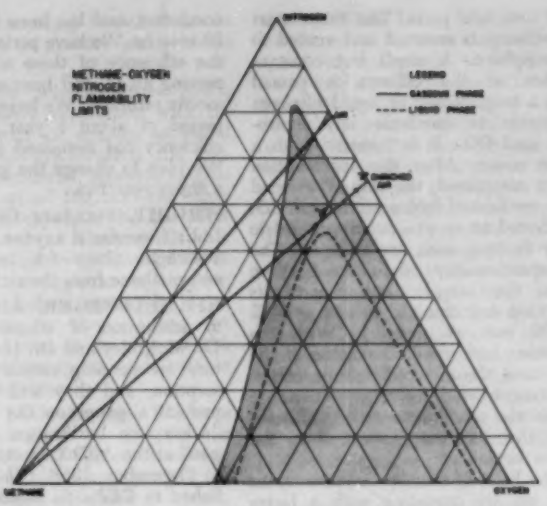

Figure 1. Flammability limits (methane-oxygen-nitrogen system.)

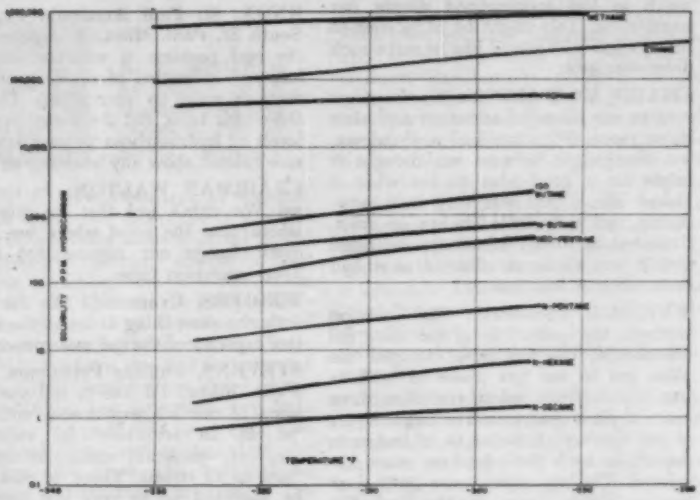

Figure 2. Solubility of saturated hydrocarbons in liquid oxygen.

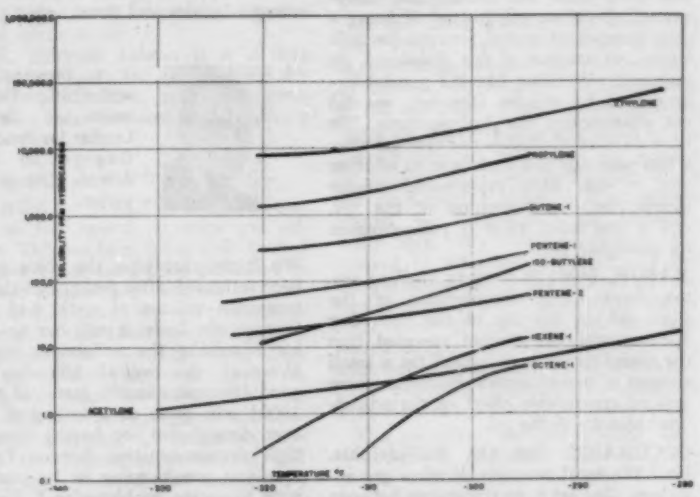

Figure 3. Solubility of unsaturated hydrocarbons in liquid oxygen.

that the solubilities of methane, ethane, and propane are above the lower explosive limit and hence could become hazardous while still in solution, but only at concentrations in excess of 50,000 pts./million when analyzed in terms of carbon atom equivalent. These three compounds have boiling points below 0°F. and are comparatively small molecules. They are the ones most likely to penetrate the air purification barriers of freeze-out and adsorption. The C_4's and higher, on the other hand, have boiling points above 0°F, and are relatively larger molecules. They are, therefore, more easily removed by normal purification methods. In fact, if an adsorber is subjected to excessive loading, beyond design expectations and safety margins, the higher boilers will preferentially displace ethane and propane. (Oxygen itself displaces methane when the inlet methane concentration is low.) One's ability to remove the less soluble compounds more readily and the fact that they tend to preferentially displace the more soluble ones from adsorbers becomes an important factor in setting maximum tolerable impurity levels. These levels must be compatible with practical operating experience and appreciably reduce monitoring requirements.

Figure 3 depicts similar data for unsaturated hydrocarbons. At C numbers 2 through 5, the unsaturates exhibit lower solubilities in liquid oxygen than the corresponding saturates. Above C_5 this distinction requires more careful definition because of a different slope in the solubility curve with respect to temperature. Again, where silica gel adsorbers are employed, nature has compensated reduced solubility with increased facility for adsorption. Generally speaking, if the adsorption bed capacity for the mixture is exceeded, the unsaturates in a liquid oxygen or liquid air stream will displace saturates of comparable C number.

Notice acetylene, as it stands out as a special character. It has a low solubility comparable to compounds which boil above 100°F., but sublimes more than 200° lower. In spite of the fact that adsorption is effective in removing acetylene, its extremely low solubility, its sensitivity to relatively low energy initiators, and its frequency of occurrence in air feeds demand that acetylene gets special treatment. More about this later.

Other factors relative to plant cycle and location must also be considered in setting tolerable impurity levels. The lower combustible limit and solubility of fuels in liquid oxygen are universal parameters which must be acknowledged. They are the primary guides. For each fuel, the tolerable level must be set at some fraction of the lower combustible limit or the solubility, whichever is smaller. The size of the fraction chosen determines the safety margin. Idealistically, this would entail frequent or continuous analysis of each fuel by mass spectrometer, chromatograph, or infrared absorption. Some operating plants are able to approach this ideal procedure. Others simplify the analytical problem by utilizing knowledge of their plant environment, the capabilities of their purification units, the equivalent carbon atom concept of combustible limits, and the significance of solubilities. A workable solution at a number of locations has been to select a limit in terms of total soluble hydrocarbons and a separate limit on acetylene. An acetylene limit of 0.5 pts./million represents a safety factor on the order of 10 when related to its solubility of 5 p.p.m. in liquid oxygen at —300°F. If complete circulation is not afforded in the reboiler, a more stringent level may be chosen to cover the possibility that liquid oxygen containing acetylene may splash on the walls above the liquid level, evaporate oxygen preferentially, and leave a residue of solid acetylene. Here, the vapor pressure of the solid acetylene becomes important. At a reboiler temperature of —290°F., the vapor pressure of solid acetylene is very low (about 4.5×10^{-6} lb./sq. in. abs.) In low-pressure, non-circulating reboilers, a safe acetylene level should be set somewhere below 0.2 pts./million.

The selection of a total soluble hydrocarbon limit in the reboiler can be based on at least three factors:

1. Air contamination levels.

In most locations hydrocarbon contaminants in air decrease in concentration as their C number increases; concentrations above 30 pts./million in air are unusual. C_4's or less are most common, and in many cases methane is greater than the sum of all other hydrocarbons combined. Site conditions can never be taken for granted, however.

2. Prepurification equipment.

The air purifying units will alter the impurity content. For example, where silica gel adsorption is employed, C_4's and above are more readily removed than lower hydrocarbons. In the event that breakthrough occurs, the lower hydrocarbons are preferentially displaced.

3. Solubilities.

The solubilities of C_4's and lower, when expressed in carbon atom equivalent, exceed 600 pts./million.

Based on these considerations, a total soluble hydrocarbon limit of 500 p.p.m. expressed in terms of carbon atoms is very realistic in many plant locations. Lowering this limit to provide an even greater margin of safety is advisable where the plant location or plant cycle will permit it. Tolerable limits, however, need not be set so low that the plant will be shut down unnecessarily.

With respect to any contaminant or any group of contaminants, the practice of setting safe limits in two steps may have merit. One level, a normal operating maximum, can be set at a value somewhat above normal or average operating concentrations in the reboiler. At some particular plant, it might be 100 pts./million for total hydrocarbons (or 0.5 pts./million for acetylene). When this level is exceeded, corrective action might be taken, such as increasing a purge or putting a fresh adsorber on stream. Diagnostic action would also be initiated to determine why an abnormal level is occurring. Action taken at this lower level of contamination may eliminate a costly plant shut-down. A second limit, including a reasonable safety factor, would represent the maximum safe concentration. It might be 500 pts./million for total hydrocarbons. When concentration exceeds this level, emergency shut-down is dictated.

* SAFETY ROUNDTABLE

Aside from hydrocarbons, other contaminants, such as initiators and sensitizers, should be mentioned, even though they are not hazardous in liquid oxygen in the absence of fuels. Ozone can be classed as an initiator and a sensitizer. Experiments have shown it capable of triggering liquid oxygen-hydrocarbon mixtures in the flammable range. Experiments have also indicated that less impact energy is required to initiate flammable mixtures in the presence of ozone. In both cases, however, ozone concentrations have been much higher than ever detected in air plants. In fact, air plant tests for ozone are seldom, if ever, positive. Nevertheless, since it is an initiator, all possible precautions should be taken to prevent ozone from entering the plant.

The oxides of nitrogen, NO and NO_2, have both sensitizing and inhibiting effects on combustion. Experiments, where NO_2 has been added to liquid oxygen-hydrocarbon mixtures just below the explosive range, have shown NO_2 to have very little or no effect on the combustible limit, nor has it shown any capability for spontaneous ignition of mixtures within the flammable range.

In the trace impurity range, oxides of nitrogen have reacted with ozone and hydrocarbons in the presence of sunlight to produce complex molecules in smog areas. At low temperature in coke oven gas plants, explosive "gums" have been formed by reactions of oxides of nitrogen and unsaturated hydrocarbon, but in concentrations of several percent rather than parts per million. These reactions prompt us to be suspicious of oxides of nitrogen, but do not define their predictable behavior in air plants such that operating limits can be set.

Toward the further understanding of their behavior, experimental work is continuing. The solubilities of NO and NO_2 in liquid oxygen at -300°F. have been determined as 6 and 15 pts./million respectively. Analytical results have shown plant concentrations to be far below this level. A tolerable limit for oxides of nitrogen might be set at 2 pts./million, or even 0.2 pts./million in many places, without handicapping operation. Setting limits below their solubility level may provide protection against some hazard as yet not clearly defined—and possibly non-existent.

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There is more to learn about initiators and sensitizers, and we are hard-pressed to select safe limits based on scientific criteria. Emphasis on prevention of hazardous fuel levels is a more certain line of safety defense. With the selection of safe limits of concentration, guideposts are set up. The next step is to prevent reboiler concentration from exceeding safe levels. One approach is to minimize contamination entering the reboiler through prepurification of the feed stream. Here, low temperature adsorption and catalytic oxidation are in established use.

The other general approach to reboiler purity is through withdrawal of all or a portion of the liquid oxygen phase which is susceptible to contamination. These include intermittent purging, continual withdrawal of a side stream to an auxiliary vaporizer or liquid pump, and other variations.

Where only part of the liquid is drawn off, the questions of how much and how often must be answered. Where analytical monitoring of the reboiler is practiced, the answers are in the safe limits. Through experience, the required withdrawal rate for a given cycle at a particular location can be predetermined approximately. On this basis, it has been possible to design so as to maintain refrigeration balances and to recover all or part of the refrigeration and product lost through partial withdrawal. Since the auxiliary vaporizer further concentrates impurities, special controls are applied. It is customary to install such units in a separate or remote part of the cold box to avoid major plant damage in the event that the additional concentration of impurities reaches hazardous proportions.

A type of reboiler system permitting complete circulation of liquid and gas taking place through a common inlet and a common outlet is shown in Figure 4.

Note that no distinct liquid level exists on the oxygen side of this reboiler. Liquid and vapor circulate completely, no unwetted walls are exposed, and continuous liquid withdrawal is taken overhead. Since the vapor phase which contains essentially no impurities forms part of the circulating stream, the most impure portion, all liquid is fed to the pump which acts as a continuous purge.

In cycles where pumps are not required, an auxiliary set of low-temperature adsorbers may be placed in a liquid stream circulating through the reboiler and the column.

The final step of maintaining a safe level of contamination in reboilers is monitoring, which provides both the windshield and the rear-view mirror to the road of safe operation.

CHAIRMAN WALTON: Thank you Mr. Himmelberger. Any comments? Has anybody had the experience of determining ozone and oxides of nitrogen concentrations above, say 0.02 pts./million? Our own analyses have not given us values greater than that. One of the questions that has been raised is the desirability of intermittent and continuous blowdown. In our own case, we practice continuous blowdown. It seems to be required to maintain a hydrocarbon concentration down to about 100 pts./million which we strive for.

FUNK, German Linde: On the question of nitrogen oxides, last year Dr. Karwat has issued a comprehensive paper on this subject, but since then we have discovered some new occurrences of several hundred parts/million of nitrous oxide, which was found in a main condenser. Of course, we had to find out whether this was of any concern, but fortunately it does not seem to be a sensitizer for explosions. It does not seem to result in or promote explosions.

CHAIRMAN WALTON: One thing that has concerned some people has been methane. Methane is rarely analyzed for. Yet we know in the cases where it has been analyzed that you'll find methane in the reboiler liquid being extremely high in number of parts/million. This is certainly a fuel and yet, it's one which is pretty well discounted in most peoeples' thinking. Does anyone have any different thoughts? The analytical techniques usually, of course, miss methane in your analyses for hydrocarbons.

G. S. Cochrane, Sun Oil, is intensely interested in air plant safety, especially infra-red analyzers.

COCHRANE, Sun Oil: Perhaps we are a little conservative in measuring total hydrocarbons, but for shutting down the plant or for taking corrective action, our hydrocarbon limits include methane. This requires the use of a separate analytical technique, gas chromatography, for measuring methane. We have developed a test which is quite sensitive in the very low parts per million range.

GRUNBERG, L'Air Liquide: Mr. Himmelberger mentioned a limit of 100 pts./million of total allowable hydrocarbons in the air treated. We have also found that it is difficult in practice to set a lower limit. Otherwise, the plants would have to shut down too frequently. When it comes to methane, its vapor pressure and solubility are so high that a much higher concentration is safe. However, the total allowable hydrocarbons in the air would have to be limited to approximately 150 p.p.m., unless very accurate and rapid methods of analysis could instantly certify that only a very small amount of hydrocarbons heavier than ethane are present in the air feed and the vaporizers.

MASON, Dow: We did some work in Midland on the solubilities and explosion limits of some various hydrocarbons in liquid oxygen, including methane. The procedure was carried on by remote control behind a barricade. We introduced measured quantities of oxygen gas and hydrocarbons into a copper vessel in which the mixture was condensed by cooling with liquid nitrogen. This condensed solution was tested for explosibility by detonation with a No. 6 Blasting Cap about 2 inches above the liquid surface. Solutions of methane up to 10% by weight did not explode, however, a solution of 33% methane exploded violently and destroyed some of the apparatus. However, the solubility of methane is so high that, as Dr. Grunberg suggested, its relatively high vapor pressure would prevent its accumulation to a dangerous concentration.

HIMMELBERGER, Air Products: In our experimental explosion work at Air Products, we ran several mixtures of methane and oxygen. Below 10% methane, no explosions resulted; mixtures above 12% exploded every time. Between 10%-12% methane, results were less consistent. We set 11% as the approximate lower explosive limit of

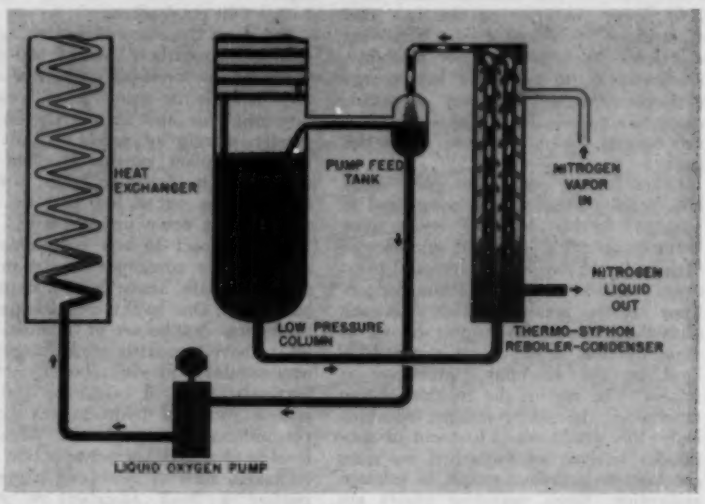

Figure 4. Circulating oxygen system.

methane in oxygen in the liquid phase. A dynamite cap was used for initiation.

DE PAUW, Carbo-chimique Testre, Belgium: There are some interesting facts about blowdown which we have experienced in our plant. We operate a plant which now has an auxiliary condenser. Some 2 years ago we were operating in a regular way. One day there was an alarm given by the plant operator who was noticing that the purge from the auxiliary condenser was showing a white color which most of you attribute to CO_2. This assumption was made by us too, but about half an hour later, a little explosion took place. This was not really dangerous but it was a warning. The findings were that there had been some CO_2 in the oxygen, although nothing indicated that the silica gel adsorbers or the heat exchangers (or regenerators) had gone wrong. On the contrary, we did not find acetylene or other hydrocarbons to be above permissible levels. Our theory is that the white color of the oxygen indicated some oxidation had already taken place initially as a kind of slow flame. Later, the reaction grew explosive. We haven't been able to trace anything further, because nothing has happened since.

WEIGERS, Cyanamid: We had an experience six months ago which may be of interest to some of you here who have auxiliary vaporizers. We make it a practice to analyze for acetylene every hour and a half in the liquid separator located underneath the auxiliary vaporizer, as well as analyzing in the main condenser reboiler of the oxygen plant. We try to run with a continuous purge by doing a partial evaporation of the liquid withdrawn from the main condenser. We had been operating for several months with absolutely no acetylene indicated when suddenly we had an appreciable concentration of acetylene in the liquid separator underneath the auxiliary vaporizer. The concentration found was much higher than what you would expect if the acetylene levels in the main vaporizer were its source. We occasionally find the merest trace of acetylene—0.02 pts./million, in this liquid oxygen separator, and under those conditions one can predict that he won't find any in the main condenser. But this time we found 3 p.p.m. and still had found nothing in the main condenser. We have theorized that the auxiliary condenser was not running with all the tubes wetted, and that in some tubes we had total evaporation taking place and that over a period of days, some acetylene crystals deposited. We had been trying to re-establish a a continuous drop-through of liquid, and just prior to this incident the operator *over-controlled* and passed too much liquid into the auxiliary condenser. We have, therefore, modified our procedures so that even when we are running with a controlled continuous liquid drop-through we still flush the additional condenser once a shift by opening the liquid feed valve so that all tubes will be wetted, preventing the accumulation of crystals in dry tubes. Since we've adopted this procedure we have no recurrence of this particular incident. Has anyone else run into a similar situation?

CHAIRMAN WALTON: As far as I know, this is the first concrete proof of the thing that has been talked about a great deal—that you could have a development of crystals above the liquid surface in a pot-type reboiler.

LAWRENCE, U.S.I.: We have had the experience that Gordon Weigers mentioned, on several occasions and we went through the same reasoning he did, except that we haven't started flushing the thing out yet. If flushing seems to work all right, it sounds like a good idea. We've noticed that we apparently on several occasions have had a dry tube suddenly get some liquid on it and wash out. We have the same type of auxiliary vaporizer as Mr. Weigers described.

WEIGERS, Cyanamid: I might add that to our minds this is the best argument for deriming your auxiliary condenser from time to time whether its fouled with CO_2 or not.

CHAIRMAN WALTON: Does anybody have any comments on intermittent blowdown as compared with continuous?

BOLLEN, Dow: Ours isn't intermittent at the present time. However, when we first started operations we were using the intermittent blowdown and we found that we got up into some pretty high concentrations of hydrocarbons. When we started operating with continuous blowdown we found it effective in keeping the concentrations down below 100 pts./million. Normally the concentration was in the order of 50 pts./million. Just recently we installed a new air compressor to supplement the air flow to the air plant. We were able to put approximately 15% more air into the air plant, but we found that we couldn't handle all of the extra liquid oxygen that was produced. Our oxygen take-off is in the vapor phase and we found that the oxygen level built up so rapidly in the vaporizer section that we had to purge a great deal more oxygen in order to control the level. Since that time, with the increase in purge we have found that the hydrocarbon content in liquid oxygen has dropped down to as low as 5 pts./million.

KNAPP, American Messer: Considering the withdrawal of the liquid oxygen from the condenser reboiler, we think that the shape of the tube sheet is an important factor. Looking at the few pictures that have been released concerning reboiler explosions, one can notice that the tubes have been damaged often near the lower tube sheet. From this one must assume that crystals that precipitate out of the over-saturated liquid settle down on the tube sheet and are not removed even if the liquid oxygen is drawn continuously from the bottom of the tube sheet. We, therefore, provide our condensers with conical lower tube sheets where the liquid oxygen is withdrawn on the lowest point in the cone and experience seems to indicate that this is effective in this respect.

FUNK, German Linde: It is an old practice in our shops to supply the main condenser with the conical tube sheet.

* SAFETY ROUNDTABLE

J.A. Glass, supervising engineering for the production Technical Service Department at Monsanto.

GLASS, Monsanto Chemical, Texas City, Texas: We have studied nitrous oxide, nitrous oxide-acetylene, and carbon dioxide-acetylene mixtures in the presence of liquid oxygen in an effort to explain the detonation which occurred at the bottom of our reboiler, as described by Bill Rotzler at the Baltimore meeting. We have found that certain mixtures of solid nitrous oxide-acetylene as well as solid carbon dioxide-acetylene will sink in liquid oxygen. We have also noted that we were unable to get an explosion of solid carbon dioxide-acetylene mixtures which are dense enough to sink in liquid oxygen. However, we found that certain mixtures of solid nitrous oxide-acetylene which sink in liquid oxygen will explode under certain conditions.

We have measured the nitrous oxide content of our oxygen reboiler drain and on several occasions found that the concentration has been in excess of the 70 p.p.m. solubility limit. These facts may explain certain detonations which occur at the bottom of the reboilers.

Instrumentation

CHAIRMAN WALTON: The next topic is instrumentation. We have Gordon Cochrane of Sun Oil Co. to introduce this topic. His company has done considerable work on instrumentation and has a great deal to offer.

COCHRANE, Sun Oil: As an introduction to the discussion on air plant instrumentation, I would like to briefly describe the infra-red analyzer installation at the Sun Oil Co. air plant at Marcus Hook, Pa. (*See Feb. '59 CEP, pp. 54-58 —Editor*).

ANONYMOUS: Mr. Cochrane, do you analyze the same stream with both the catalytic oxidation unit and the hydrocarbon unit itself, or do you monitor different streams with the different analyzers?

COCHRANE: We normally monitor different streams with different analyzers. The reason we installed the two types of analyzers was that when we first

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Safety Symposium

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investigated the analyzers there was no experience with the catalytic oxidation catalyst. So we installed the one analyzer which did not involve catalytic oxidation as a check on the effectiveness of the catalyst in the other analyzers. We normally use it on a separate stream. However, we have compared the results of the two analyzers on the same stream.

ANONYMOUS: When you're using catalytic oxidation, is there any possibility of your being deceived by picking up, say, a heavy molecule and getting a lot of CO_2 where actually you have an acetylene molecule, which is actually much more critical?

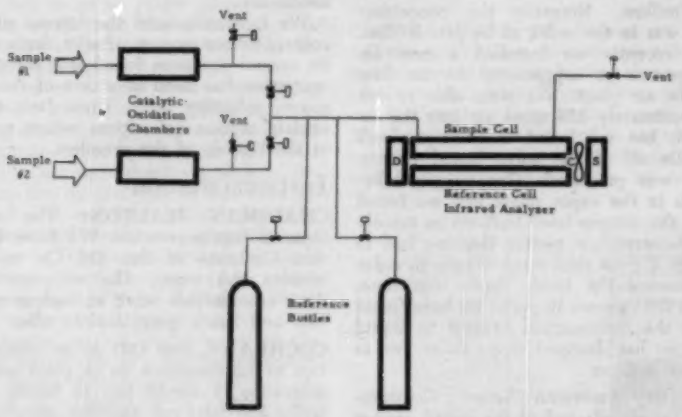
COCHRANE: That's right. In measuring total hydrocarbons by catalytic oxidation a heavy molecule will show up as a much greater concentration of carbon dioxide. It will be proportional to the total pounds of carbon present in the sample. That is why it is essential that the analyzer readings be supplemented by a complete hydrocarbon breakdown. As far as acetylene is concerned, it is a completely different problem. We analyze it separately in a chemical test. We do not rely at all on the analyzers to tell us the concentration of acetylene in the stream. I know that MSA has a special analyzer which you can sensitize to acetylene in areas where acetylene is a problem. We do not have such an analyzer.

COCHRANE: We do not analyze the high pressure column bottoms. The high pressure column feed is what we analyze.

CHAIRMAN WALTON: As I recall, there's a period of about 1 to 2 hours from the time that you get a big surge on the intake until you can see it in the reboiler. So this is a marvelous protective device if you have problems with high hydrocarbons in your air intake. In the Philadelphia area, one of the things which is significant is you normally always have a fishtail type of wind. The wind is continually going back and forth over about a 25-degree range and that is one of the things which tends to give you these ups and downs in the hydrocarbon content of your air intake. Rohm & Haas has an MSA Acetylene Analyser, an installation that has been in service for about a year. I wonder if they would care to comment on it.

WALTON, Rohm & Haas: We have an analyzer, the MSA-type analyzer. We've had it in service approximately six months. However, we have not yet made use of it as far as determining acetylene goes—our chemical methods do not indicate any.

CHAIRMAN WALTON: You get zero reading on it and that checks with your chemical methods? Well, we have an MSA analyzer at Atlantic which has been installed but has not been in operation yet because of purely sampling problems. We've been having difficulty in getting a liquid sample to the analyzer. The analyzer itself has checked out well on knowns. I think probably



Infrared analyzer installation for monitoring total hydrocarbons. (Sun Oil.)

WEIGERS, Cyanamid: You mentioned that you analyzed the rich liquid stream from your pressure column. What's the significance of the analysis? I'm assuming that you have liquid phase adsorbers which I gather are not too good for some of the lower hydrocarbons but why do you analyze there in addition to the liquid oxygen in your main reboiler condenser?

just about this time back home they're putting it on again with an improved sampling device. Anybody else have any comments on MSA?

MASON, Dow: At Midland, we have a continuous hydrocarbon analyzer which was built by our Spectroscopy Department using the Mines Safety Appliance Detector. This unit has been in operation on compressor air intake for nearly a year with very little trouble. There was some electronic noise introduced at one time by some dirty contacts. This trouble was eliminated by a thorough cleaning. At one other time, a tube failure gave us a scare. Also, there seems to be some drift of the zero point from day to night which worried us at first. This instrument usually reads at, or very near, zero, but has gone up to as high as ten p.p.m. for very short periods of time. This analyzer is tested daily using a sample of known composition of ethane and air.

WEIGERS, Cyanamid: We also have one of the MSA infra-red analyzers which is sensitized to acetylene. We are using it to sample the incoming air stream. We are getting the liquid sample devices in the hope of setting up for an acetylene determination in the liquid oxygen. Our analyzer takes the sample from the air feed to the high pressure column. We've had it continuously onstream since October of 1957 and our operating experience is unfortunately rather limited. There's been only one incident of acetylene since the analyzer went on stream and that was corroborated by chemical analysis. The particular analyzer that we have has a zero to 4 p.p.m. full scale deflection and with the noise level that we're experiencing a trained observer could probably interpret 0.2 of a p.p.m. but as far as our operators are concerned 0.3 of a p.p.m. would be the minimum significant deflection.

SANDERS, Texas Co., Lockport, Ill.: We're doing something a little bit different, however. We're monitoring the separator liquid oxygen as the most concentrated source of contaminants and we're applying the same, or essentially the same, contaminant limits as most everyone appears to be applying to their low pressure tower or reboiler liquids. We've used this to its greatest advantage in telling us when we had corrected some particular contaminant problem by either purging or by switching the rich liquid or the cold filters. And just a comment which applies to what we've said this morning—the fastest correction we've found is by switching the cold filters on high hydrocarbon counts.

COCHRANE, Sun Oil: I would just like to mention briefly some of the other uses to which we have put our infra-red analyzers. One has been to study defrost of the silica gel adsorbers and defrost of some of our exchangers. We have tried also to measure the hydrocarbons removed from a plant during defrost and where those hydrocarbons were coming from.

CHAIRMAN WALTON: That's a very good point because I know some of us have had difficulties with blockage in nitrogen wash systems in hydrogen purification and the use of the analyzer to try and determine just what it is that is causing that blockage would certainly be a very valuable tool.

Part 2 of this three part report will appear in the July issue of CEP.

Solution of Nonlinear chemical engineering models

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Nonlinear statistics is a powerful tool rapidly moving in to fill the gap between the wholly theoretical model and the completely empirical model. The least-squares fitting of nonlinear models to expermental data is discussed.

Nonlinear statistics may be expected to assume increasing importance in Chemical Engineering, despite the small amount of attention the subject has received in the past. This presentation is more concerned with introductory ideas than with details, although sufficient detail is provided to get the reader started in the practical use of nonlinear statistical models. Widespread use of the general concept of the **mathematical model** is quite recent, following upon the heels of the commercial availability of modern computers. A mathematical model is simply a mathematical relationship capable of quantitatively describing a physical system.

Some mathematical models are based upon a high degree of **theoretical understanding** of the physical system, and, typically, such models are composed of nonlinear differential equations whose solutions are studied numerically on the computer. At the other extreme are the largely empirical models, typically expressed by least-squares polynomials, which describe the response of the physical system to changes in the independent variables. These polynomial-type models draw upon the large body of statistical techniques comprising linear least-squares theory. As a generalization, the statistics of nonlinear models applies to the semi-theoretical region between these two ends of the spectrum of mathematical models. The theoretical background we can bring to bear, in the construction of a really adequate mathematical model for a particular physical system, is seldom sufficient to avoid empirical—therefore statistical—aspects entirely. At the same time it is infrequent that we have no theoretical knowledge whatever, about the important physical mechanisms. Consequently, it is to be expected that nonlinear statistics will have wide applicability.

The emphasis here will be on algebraic nonlinear models, which comprise the most straightforward area of application of nonlinear statistics. By an algebraic statistical model is meant a known explicit algebraic (or transcendental) expression for a measurable dependent variable, y, as a function of one or more independent

continued

. . . a nonlinear statistical model . . . is likely to yield more meaningful results, and more rapid technical progress.

continued

variables $x_1, x_2, \ldots, x_m$. The algebraic expression will contain some unknown parameters $\beta_1, \beta_2, \ldots, \beta_k$ for which numerical values are to be obtained from a set of data.

When faced with a physical system about which not enough is known to write a complete theoretical model, it is temptingly easy to retreat to a simple polynomial-type statistical model, ignoring whatever partial theoretical understanding is available. This is obviously wasteful, and may actually be a hindrance to progress. The semi-theoretical alternate is usually a nonlinear statistical model, which, although requiring more computational effort, is likely to yield more meaningful results, and more rapid technical progress.

Distinction between linear and nonlinear models

The *linearity* or *nonlinearity* of a statistical model describes the manner in which the unknown parameters enter into the algebraic expression. For example:

To fit experimental data giving measured values of vapor pressure P, at various temperatures t, we can choose our model from a variety of algebraic expressions; typical are:

$$P=\beta_1+\beta_2 t+\beta_3 t^2 \qquad (1)$$

$$P=\exp\left(\beta_1+\frac{\beta_2}{\beta_3+t}\right) \qquad (2)$$

Equation (1) is a polynomial-type model, linear in the unknown parameters $\beta_1, \beta_2, \beta_3$, because these parameters enter in the *first degree*. The second expression is a vapor pressure model of the Antoine type; it is nonlinear in the parameters $\beta_1, \beta_2, \beta_3$. Both expressions are, of course, nonlinear in the independent variable, t, but this fact is irrelevant to the linearity of the statistical problem. For expressing vapor pressure data, the Antoine-type model is generally to be preferred because the semi-theoretical character of the expression usually leads to a closer fit to the data, with the same number of unknown parameters, and to a greater confidence in interpolation and extrapolation of the fitted curve, if that should be necessary. A further desirable feature of theoretically-based models is that their parameters frequently can be given specific physical interpretation, leading to better understanding of the physical mechanism.

Some general statistical considerations

The algebraic expression relating the dependent variable to the independent variables is denoted by the general *functional notation:*

$$y=f(x_1, x_2, \ldots, x_m; \beta_1, \beta_2, \ldots, \beta_k) \qquad (3)$$

The function f may be either linear or nonlinear in the parameters $\beta_1, \beta_2, \ldots, \beta_k$.

The experimental data points are denoted as

$$(Y_i, X_{1i}, X_{2i}, \ldots, X_{mi});\ i=1, 2, \ldots, n \qquad (4)$$

Now, statistical techniques are always based upon the concept of a particular set of data (called a **sample**) having been drawn from a larger—usually hypothetical and infinitely large—**population** of values. The unknown parameters of the model are those characteristic of the population. From the sample we obtain **estimates** of the population parameters. Since the estimates obtained from different samples will vary, although the population values being estimated are invariant, separate symbols are used to draw attention to the distinction between *population* and *sample* values of the parameters. The sample values of $\beta_1, \beta_2, \ldots, \beta_k$ will be denoted by $b_1, b_2, \ldots, b_k$.

In most circumstances, the appropriate statistical criterion for adjusting the values of the parameters to best fit the data, is the **least-squares criterion.** Let $\hat{Y}_i$ denote the **predicted value** obtained for y when, for the *ith* data point, the values of the independent variables are substituted into Equation (3). Thus,

$$\hat{Y}_i=f(X_{1i}, X_{2i}, \ldots, X_{mi}; b_1, b_2, \ldots, b_k) \qquad (5)$$

By the least-squares criterion, the unknown parameters are to be adjusted until

$$\Phi=\sum_{i=1}^{n}\left[Y_i-\hat{Y}_i\right]^2 \qquad (6)$$

is a minimum. The parameter values

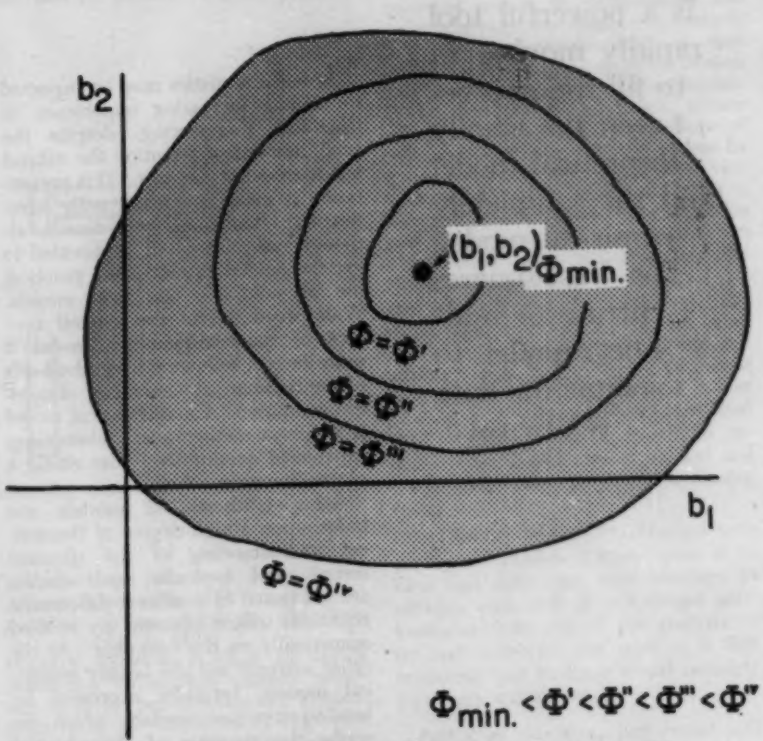

Figure 1. Hypothetical contour surface of Φ as a function of b_1 and b_2

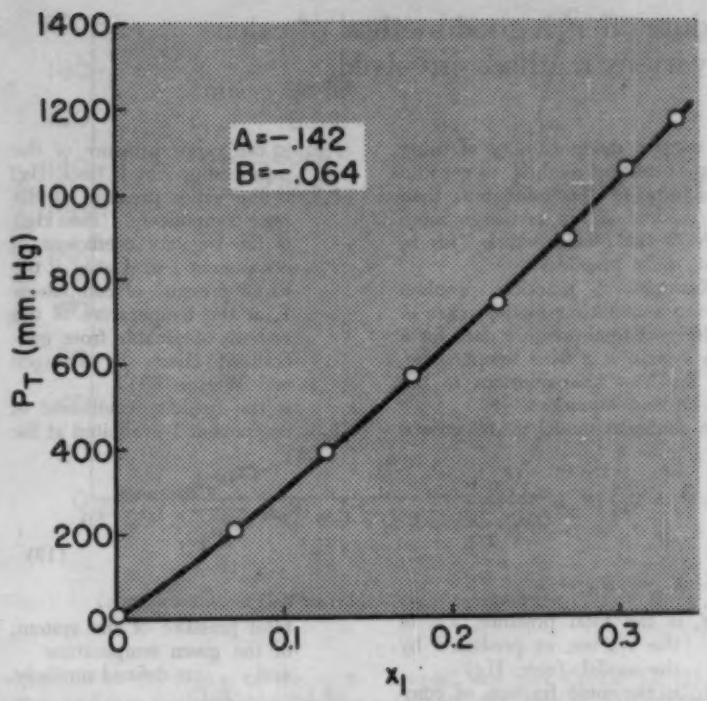

Figure 2. Van Laar fit of methylacetylene—DMF equilibrium data at 20°C

so obtained are then the least-squares estimates of $\beta_1, \beta_2, \ldots, \beta_k$.

Whenever the function f is linear in the unknown parameters, it is a straightforward operation to find the least-squares estimates. This is done by setting the partial derivatives of Φ equal to zero, and solving the resulting simultaneous linear equations for $b_1, b_2, \ldots, b_k$. Thus,

$$\left.\begin{aligned} \frac{\partial \Phi}{\partial b_1} &= 0 \\ \frac{\partial \Phi}{\partial b_2} &= 0 \\ &\vdots \\ \frac{\partial \Phi}{\partial b_k} &= 0 \end{aligned}\right\} \quad (7)$$

In practice there are many fine points of methodology in handling the simultaneous Equations (7), but the important point here is that they are linear equations.

If the function f is nonlinear in the parameters, then, were the Equations (7) to be written out, they would be found to be nonlinear, simultaneous equations, whose solution is not straightforward. Here, then, is the first major practical problem: to estimate the nonlinear parameters in the least-squares sense, economically.*

Working with the nonlinear model

Case I: Linearization of the mathematics, while retaining the nonlinear physical model.

In certain cases, it is possible to linearize the mathematics required to fit the nonlinear model to the experimental data. The Antoine model, Equation (2), is an example. Simple techniques to do this are described on page 69. The general, dimensional analysis model (also discussed later) is another nonlinear model of wide applicability which can be linearized by an appropriate set of transformations. Unfortunately, the cases where a linearizing transformation can be found form a minority of the cases met in practice.

Case II: Determination of the least-squares estimates by direct trial-and-error minimization of Φ.

In the general case, the nonlinear model must be fitted as it stands. Iterative (trial-and-error) techniques are required. Instead of trying to solve Equations (7), it is simpler to minimize Φ directly. Two variations of this approach are available:

a. The nonlinear model, Equation (5), may be expanded into a Taylor series about the current trial values for the parameters (*7, 8, 13*). If the Taylor series is truncated after the linear terms, then the resulting expression is linear in corrections to the parameters. Thus, taking $b_1^{(r)}, b_2^{(r)}, \ldots, b_k^{(r)}$ as the $(r)th$ trial values, and $\Delta b_1^{(r)}, \ldots, \Delta b_k^{(r)}$ as corrections to be calculated:

$$\hat{Y}_i \cong f_i^{(r)} + \Delta b_1^{(r)}\left(\frac{\partial f_1}{\partial b_1}\right)^{(r)} + \Delta b_2^{(r)}\left(\frac{\partial f_1}{\partial b_2}\right)^{(r)} + \ldots + \Delta b_k^{(r)}\left(\frac{\partial f_1}{\partial b}\right)^{(r)} \quad (8)$$

where the superscript r denotes numerical evaluation, using the values for the parameters at the rth trial, and the subscript i denotes numerical evaluation, using the values of the independent variables for the ith data point. If the right-hand side of Equation (8) is substituted for $\hat{Y}_i$ in Equation (6), then linear equations of the form

$$\left.\begin{aligned} \left(\frac{\partial \Phi}{\partial (\Delta b_1)}\right)^{(r)} &= 0 \\ \left(\frac{\partial \Phi}{\partial (\Delta b_2)}\right)^{(r)} &= 0 \\ &\vdots \\ \left(\frac{\partial \Phi}{\partial (\Delta b_k)}\right)^{(r)} &= 0 \end{aligned}\right\} \quad (9)$$

analogous to Equation (7), can be written. Solving for the corrections to the parameters, the $(r+1)st$ trial values are calculated from

$$b_1^{(r+1)} = b_1^{(r)} + \Delta b_1^{(r)}, \text{ etc.} \quad (10)$$

This procedure is repeated until the corrections become negligible, that is, until convergence of the iteration to the least-squares estimates. This method converges rapidly, but only if the initial guesses for the unknown parameters are quite good. Otherwise, the method diverges.

b. By expanding Φ into a Taylor series, the minimization may be ac-

* *Other major problems are the calculation of confidence regions for the parameters, and the design of optimum experiments. These problems are not discussed in this presentation.*

. . . steepest-descent type procedure offers a good method of calculation, here are details of the various methods involved.

continued

complished by a **steepest-descent** type procedure. In effect, this approach seeks to calculate corrections such that at each iteration the value of Φ will decrease "most rapidly." Thus, if we think of the positive quantity Φ as defining a "contour surface" as the unknown parameters are varied, the steepest-descent procedure determines the corrections which are in the steepest downhill direction from the current trial values, [*CEP*, April '59, p. 64]. Figure 1 shows a hypothetical contour surface for a case with only two parameters, b_1, b_2. In general, the steepest-descent direction is defined by the quantities

$$\left(\frac{\partial \Phi}{\partial b_1}\right)^{(r)}, \left(\frac{\partial \Phi}{\partial b_2}\right)^{(r)}, \ldots, \left(\frac{\partial \Phi}{\partial b_k}\right)^{(r)} \quad (11)$$

which are the rates of change of Φ with respect to each of the unknown parameters, evaluated at the *rth* trial values of the parameters. Now, for reasons stated on page 69 it is not desirable to make the corrections exactly proportional to the partial derivatives of Φ. Instead, the corrections are determined for a *modified steepest-descent*; for example,

$$b_1^{(r+1)} = b_1^{(r)} + \Delta b_1^{(r)} = b_1^{(r)} + \alpha^{(r)} N_1^{(r)} \quad (12)$$

where:

$$N_1^{(r)} = \frac{[1+(b_1^{(r)})^2]\left(\frac{\partial \Phi}{\partial b_1}\right)^{(r)}}{\left[\sum_{j=1}^{k}\left([1+(b_j^{(r)})^2]\left(\frac{\partial \Phi}{\partial b_j}\right)^{(r)}\right)^2\right]^{1/2}}$$

etc. for $b_2^{(r+1)}, \ldots, b_k^{(r+1)}$

The quantity $N_1^{(r)}$ is simply the *normalized* value of the partial derivative, after multiplication by the factor $[1 + (b_1^{(r)})^2]$. These quantities $N_1^{(r)}$, $N_2^{(r)}$, etc., determine the *relative* sizes of $\Delta b_1^{(r)}$, $\Delta b_2^{(r)}$, etc., and their signs. The quantity $\alpha^{(r)}$ is the **step size**, which determines the **absolute** magnitudes of the corrections. It should be adjusted from trial to trial, as described on page 70.

The modified steepest-descent method converges slower than method (a), but has the distinct advantage of converging from *almost any* reasonable first guess. This should immediately suggest the possibility of using a steepest-descent method, to get into the **vicinity of the minimum**, then using method (a) to converge more rapidly to the precise value. This is, indeed, quite practical.

An Example. A practical problem involving a nonlinear model arises in the fitting of total-pressure data for a binary system at a fixed temperature, using the Van Laar-solutions to the Gibbs-Duhem equations.

The nonlinear model in this case is

$$P_T = \hat{Y}_i = X_{1i}(P_0)_1 \frac{\nu_{(P_0)_1}}{\nu_{(P_T)_1}} \gamma_1 + X_{2i}(P_0)_2 \frac{\nu_{(P_0)_2}}{\nu_{(P_T)_2}} \gamma_2 \quad (13)$$

where: $X_{1i} + X_{2i} = 1$

and $\hat{Y}_i$ is the total pressure, P_T, of the system, as predicted by the model, (mm. Hg)

X_{1i} is the mole fraction of component 1 in the liquid phase

X_{2i} is the mole fraction of component 2 (solvent) in the liquid phase

$(P_0)_1$ is the vapor pressure of the pure component 1, (mm. Hg)

$(P_0)_2$ is the vapor pressure of the pure component 2, (mm. Hg)

$\nu_{(P_0)_1}$ is the fugacity coefficient of component 1 evaluated at the vapor pressure of component 1, at the temperature of the system; obtainable from generalized charts by Hougen and Watson (9)

$\nu_{(P_T)_1}$ is the fugacity coefficient of component 1 evaluated at the total pressure of the system, at the given temperature

$\nu_{(P_0)_2}$ and $\nu_{(P_T)_2}$ are defined similarly.

$$\gamma_1 = \exp\left(\frac{A}{\left[1+\frac{AX_{1i}}{BX_{2i}}\right]^2}\right)$$

$$\gamma_2 = \exp\left(\frac{B}{\left[1+\frac{BX_{2i}}{AX_{1i}}\right]^2}\right)$$

A, B are unknown parameters to be estimated. For simplicity, their *estimates* will also be denoted A, B. The magnitudes of A, B are a measure of the deviation from ideal solution behavior.

Experimental data for the binary system methyl acetylene—DMF, at 20°C. and the curve representing the least-squares fit of the model of Equation (13), are shown on Figure 2. Figure 3 shows the contour surface of Φ generated by the data. It should be noted that the contour surface is

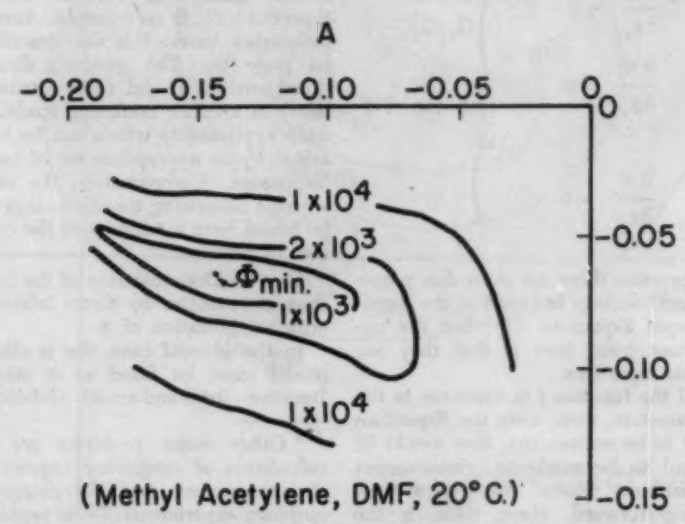

Figure 3. Van Laar Problem: Contour Surface—Lines of constant Φ

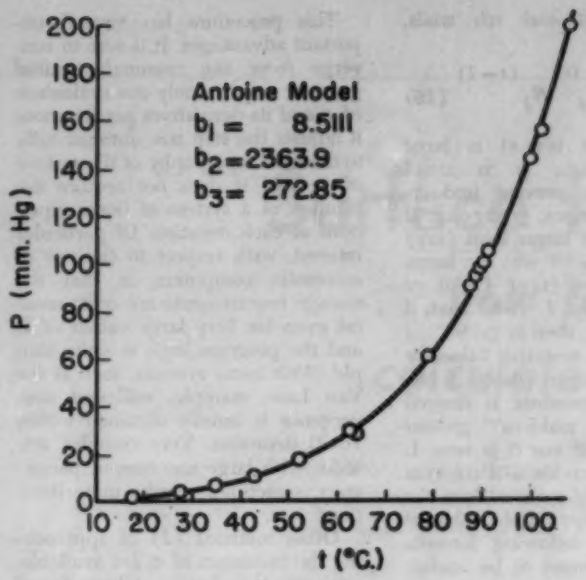

Figure 4. Vapor pressure of DMF as a function of temperature

elongated in the region of the minimum, and that the bottom of the long trough in the surface is markedly curved. The value of Φ at the minimum, (the "Residual Sum of Squares", in statistical terminology) is 292.5. The standard error of estimate, $s_e = [\Phi_{min.}/(n-k)]^{1/2}$, is 7.6 mm. Hg, which is roughly the same as the experimental error, indicating that the model is adequate to represent the data. Approximate 90%-confidence limits for the parameters are

$A = -0.142 \pm 0.008$,

$B = -0.064 \pm 0.003$. These limits were obtained by a procedure analogous to that used by Box and Coutie (*3*).

By calculating Van Laar-fits to data at other temperatures covering the range –40° to 100°C., the behavior of A and B as functions of temperature was determined, thus providing a basis for calculating the behavior of the system at any intermediate temperature. Further, data for a number of other organic gases in mixture with DMF have been similarly fitted with the Van Laar model, enabling comparisons of A and B among systems as well.

Other types of nonlinear models

It is not really necessary that the model be in the form of an explicit expression for y. It is essential only that, given values for the independent variables and parameters, it is possible to compute corresponding values for the dependent variable. For example, Box and Coutie (*2, 3*) considered the use of the differential equations of a reaction system as the model, the rate constants being unknown parameters, and concentration profiles (computed by numerical integration) the predicted dependent variable, to be matched in the least-squares sense to the observed concentration profile. In such cases, the derivatives of Φ must be approximated by finite-difference expressions.

Nonlinear statistics is rapidly moving in to fill the gap between the wholly theoretical model and the completely empirical model. This gap is large, but the tool is powerful, and its use will continue to grow.

Details of the methods

Linearization of the model

A simple set of transformations will *linearize* the simultaneous equations corresponding to the Antoine vapor pressure model. The solution thus obtained does involve an approximation, but the fit obtained, with data from a wide variety of physical systems has been uniformly good. The transformations required are derived by rearranging the equation as follows (*11, 12*):

$$lnP = \left(\beta_1 + \frac{\beta_2}{\beta_3}\right) + \frac{\beta_1}{\beta_3}\,t - \frac{1}{\beta_3(t+lnP)} \quad (14)$$

On substituting: $Y = lnP$, $X_1 = t$, $X_2 = t\ lnP$ and $\beta_1^{\circ} = \beta_1 + (\beta_2/\beta_3)$, $\beta_2^{\circ} = \beta_1/\beta_3$, $\beta_3^{\circ} = -1/\beta_3$, then the model becomes linear in β_1°, β_2°, β_3°. The approximation involved is the use of the dependent variable in the definition of X_2. Figure 4 shows experimental data of the vapor pressure of DMF, and the least-squares fit using this linearized least-squares method. (The customary base-10 logs were used for the numerical results shown in Figure 4.)

A second type of nonlinear model which is amenable to linearization by an appropriate set of transformations has been discussed in detail by Levenspiel, *et al.* (*10*). The problem they considered was that of determining the parameters β_1°, β_2, β_3, . . . β_k in a dimensional analysis model of the form

$$D_1 = \beta_1^{\circ}\,(D_2)^{\beta_2}\,(D_3)^{\beta_3} \ldots (D_k)^{\beta_k} \quad (15)$$

in which D_1, D_2, . . . , D_k are dimensionless groups. By taking logarithms of both sides of Equation (*15*), and letting $Y = \log D_1$, $X_1 = \log D_2$, $X_2 = \log D_3$, . . . , $X_m = \log D_k$, and $\beta_1 = \log \beta_1^{\circ}$, a linear model is obtained.

The modified steepest-descent

In the practical use of the steepest-descent method, one frequently finds that the contour lines on the surface of Φ are not approximately circular, as depicted in the two-dimensional case of Figure 1, but are elongated, as in Figure 3. In such cases, the steepest-descent direction at any trial value near the bottom of the "trough" is nearly at right angles to the direction from the current point to the point where Φ is a minimum. The path taken by the successive trials of the straightforward steepest-descent procedure is then a zig-zag path which crosses and re-crosses the bottom of the trough on successive trials, approaching the minimum quite slowly. One mathematical help for this difficulty is to determine a new metric (measure of distance) in the k-dimensional space of the parameters. By so doing, a metrized steepest-descent direction can be determined, which will be directed more nearly toward the point where Φ is a minimum.

A useful metric is obtained by measuring distance in terms of $\tan^{-1}b_1$, $\tan^{-1}b_2$, etc. These transformations lead to the computing formula given in Equation (*12*).

It remains to formulate a method for specifying the step size $\alpha^{(r)}$. To begin with, it is clear that it must be required that $\Phi^{(r+1)} < \Phi^{(r)}$. There will always be an $\alpha_0^{(r)}$ such that, if $\alpha^{(r)} < \alpha_0^{(r)}$ this requirement will be met, unless the r*th* trial is exactly at the minimum of Φ. On the other

continued

Non linear models

continued

hand, it is necessary to make $\alpha^{(r)}$ as large as practicable within this limitation, to approach the minimum of Φ with all possible haste. The basis of an appropriate procedure has been given by Brown, *et al.* (*3*) Observe that each set of trial values for the parameters defines a point in k-dimensional space. If, in the parameter space, the steepest-descent process produces successive trial values which lie along a straight line (or nearly so) then α is too small. If the angles between the successive trial values are large, then α is too big. Thus, α should be increased or decreased according to the angles between successive trial values. The following step-by-step procedure is a refinement of this idea.

Assuming that the calculations have proceeded through the (r—1)*st* iteration, and it is now desired to advance from the *rth* to the (r+1)*st* iteration, the succession of events is:

1. Calculate $\Phi^{(r)}$ and $N_1^{(r)}, N_2^{(r)}, \ldots, N_k^{(r)}$
2. Verify that $\Phi^{(r)} < \Phi^{(r-1)}$. (If it is not, then the tentative value for $\alpha^{(r-1)}$ was too large. Divide α by (say) 4 and go back to *step 1*.)
3. Calculate the cosine of the angle Θ, between the metrized steepest-descent directions at the (r-1)*st* and *rth* trials, using

$$\cos\Theta = \sum_{j=1}^{k} N_j^{(r)} N_j^{(r-1)} \qquad (16)$$

4. Verify that $\cos\Theta$ is large enough (i.e., Θ is small enough) to prevent undesirable oscillations, or zig-zag. If $\cos\Theta$ is not larger than (say) zero, then $\alpha^{(r-1)}$ was too large. Divide α by (say) 4 and go back to *step 1*. Note that if $\cos\Theta < 0$, then $\Theta > 90°$.
5. Calculate a tentative value for $\alpha^{(r)}$ based upon $\cos\Theta$. A calculation procedure is desired which will make $\alpha^{(r)}$ greater than $\alpha^{(r-1)}$ if $\cos\Theta$ is near 1, but will decrease α if $\cos\Theta$ is only slightly greater than the minimum acceptable value of zero. The following formula has been found to be useful:

$$\alpha^{(r)} = \alpha^{(r-1)}(d_1 + d_2\cos^4\theta)$$

where

$$0 < d_1 < 1$$

$$(1-d_1) < d_2 \leq 1 \qquad (17)$$

In particular, the combination $d_1 = 0.5$, $d_2 = 1$, is satisfactory.

6. Calculate the new trial values and return to *step 1* to begin the next iteration.

This procedure has several important advantages. It is sure to converge *from any reasonable initial guess;* it requires only one evaluation of Φ and its derivatives per iteration; it adjusts the step size automatically to the local topography of the surface of Φ; and it does not require the solution of a system of linear equations at each iteration. Of particular interest, with respect to the use of automatic computers, is that the storage requirements are quite modest even for very large values of k, and the program logic is quite simple. With many systems, such as the Van Laar example, sufficient convergence is usually obtained within 15-20 iterations. Very complex systems, with large numbers of parameters, sometimes require more iterations.

Other methods (*1*) of approaching the minimum of Φ are available, although they have not been found to be as desirable as the ones described. For example, one can use the experimental techniques developed by Box, et al. (*3, 4*) to seek the minimum. Some methods (*6*) make use of the second-partial derivatives.

NOTATION

α	Distance along the direction of steepest - descent	$x_1, x_2, \ldots, x_m$	Independent variables in a mathematical model
$\beta_1, \beta_2, \ldots, \beta_k$	Population values of the parameters in a mathematical model	y	Dependent variable in a mathematical model
Φ	Sum of squares of deviations of observed points from predicted points	$D_1, D_2, \ldots, D_k$	Dimensionless groups
Θ	Angle between the direction of steepest descent of successive trial values	$N_1, N_2, \ldots, N_k$	Components of the normalized, metrized, gradient vector
$b_1, b_2, \ldots, b_k$	Estimates of $\beta_1, \beta_2, \ldots, \beta_k$ obtained from the data	P	Pressure, mm. Hg
d_1, d_2	Constants used in the calculation of α	$X_{1i}, X_{2i}, \ldots, X_{mi}$	Values of the independent variables at the *ith* observation
f	A function	Y_i	Value of the dependent variable at the *ith* observation
t	Temperature, °C	$\hat{Y}_i$	Predicted value of the dependent variable at the *ith* observation

ACKNOWLEDGEMENT

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Surface fouling

... how to calculate limits

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IT IS THE OBJECT of this analysis to establish physical and mathematical relationships between an allowable pressure drop and the accumulation of dirt with time.

In the literature, the only mathematical postulation involving thermal surface fouling was presented by McCabe and Robinson (*1*). They arrived at an equation to show the variation of the dirty over-all film coefficient with time, in which the film coefficient varies inversely with the square root of the time.

Their approach employs a time independent constant temperature difference which occurs frequently in evaporation. Their analysis in the form in which they have developed it is not applicable when one or both of the fluids undergoes a change in sensible heat.

As an initial effort in resolving a problem of real complexity, this study is concerned with the simplest element of dirt deposition; namely the process as it occurs inside a tube of uniform diameter. To lend generality to the analysis, the distinction between dirt deposition and scale need only be considered as a matter of degree, since scale build-up also shows the same kind of inverse rate of accumulation with changing fluid linear velocities.

The decreasing rate of dirt deposition with increasing fluid linear velocity suggests the influence of fluid shear as an agent for removing dirt at the fluid-dirt interface. Fouled exchangers can often be cleaned to some extent by temporarily increasing the velocity of the circulating fluid.

In the area of engineering mathematics, two common tools suggest themselves as a means of describing the kinetics of dirt accumulation. By considering accumulation the result of continuing simultaneous processes of dirt deposition at right angles to the bulk flow and dirt removal by fluid shear in the direction of fluid flow, a potential might be expressed for accumulation and another potential for removal.

The net accumulation can be expressed as a quotient with a deposition term in the numerator and a removal term in the denominator. It can also be expressed using deposition as a series of terms, and removal as a series of terms, so that the net accumulation is obtained by subtraction. Several theoretical fouling mechanisms were tested by both types of approach. The use of difference terms proves much more rewarding than quotients because of the tendency in the latter for variables to cancel out and lose identity as fluid dynamic entities.

Occasionally, a graph appears in the literature which is the case history of the fouling of a particular piece of equipment with time. A representative graph obtained by Katz, Knudsen, Balekjian and Grover (*2*) for oil outside water-cooled tubes has been investigated. Their curves add confirmation of the fact that the fouling resistance grows asymptotically with time. These curves can be approximated by a transient equation of the form:

$$R_\theta = R^*(1 - e^{-B\theta}) \qquad (1)$$

R^* is the value of R_θ at the asymptote.

For convenience, let us start with the postulation of a removal potential. A flowing fluid exerts a shear stress τ at a wall which can be related to the friction factor f. It will be assumed that the friction factor is constant and independent of the presence or quantity of dirt. The shear stress on the wall, dirty or clean, is readily shown to be:

$$\tau = \frac{2fV^2\rho}{4g} \qquad (2)$$

If the dirt film is thin, V and τ remain unchanged during the period in which the dirt accumulates. The deposition potential depends upon the form of the driving force. From Eq. 2 it appears that if curves of the type observed by Katz et. al. are to be obtained, then the deposition term itself must impart the asymptotic inflection. This suggests a driving force equation of the form:

$$\text{Driving force} = c\,e^{-B\theta} \qquad (3)$$

where c and B are constants. The fouling resistance is then:

$$R = \frac{4cg}{2fV^2\rho B}(1 - e^{-B\theta}) \qquad (4)$$

continued

Surface fouling

continued

It will be assumed that the rate of transport and deposition are constant with time. The constant rate of deposition can be expressed quantitatively in simple form.

Rate of deposition $= K_1 c' W$ (5)

where K_1 is a proportionality constant, W is the constant weight flow of fluid, and c' is its unit dirt content.

To permit an expression for the *rate* of removal, it will be assumed that: (*1*) removal is due to the shearing action of the stream at the surface of the dirt; (2) instead of being removed particle-by-particle as is deposition, dirt is sheared off in chunks at random planes of weakness in the dirt; (3) there is a probability that planes of weakness are likely to occur at any depth.

We can express the removal rate in a form similar to Eq. 5 for the rate of deposition: (Eqs. 6 and 7, below.)

If the thickness of the film as it grows appreciably affects the linear velocity and, hence the shear stress; this variation may be included by introducing the Blasius equation.

The shear stress may be written: (See Eqs. 8, 9 and 10, below.)

The implications of Eq. 10 are shown in Fig. 1.

Having obtained a relationship between weight flow, film thickness and time we now proceed to a relationship between the film thickness and the pressure drop ΔP.

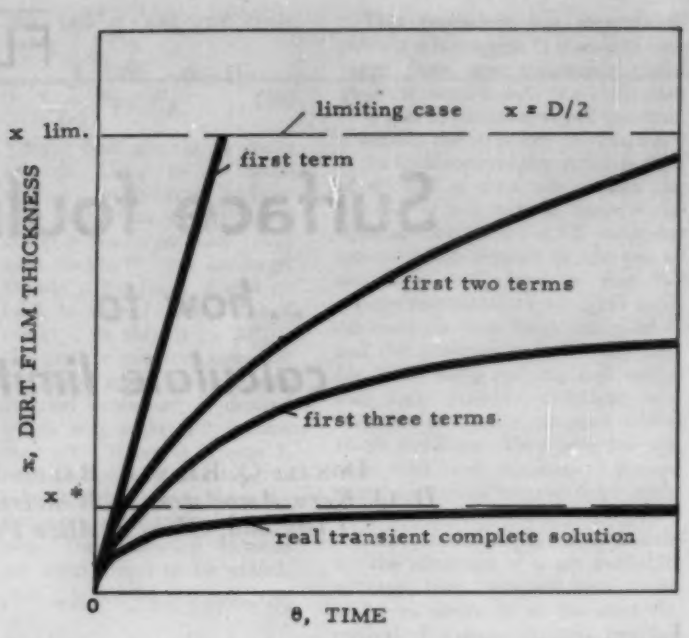

Figure 1. The implications involved in Equation 10 are shown by this plot of Equation 10 with arbitrary constants.

Utilizing Eqs. 2, 7 and 8, it is easily shown that: (See Eq. 11, below.)

This general case is integrable by computer. However, of greater interest is the particular solution relating the thickness of the dirt at any asymptotic deposition and the pressure drop required to attain it. From Eq. 11 it is apparent that a different asymptote can exist for each allowable pressure drop. The matter now becomes one of determining how much energy is required to reduce the asymptotic thickness of the dirt to a point where it becomes a permanently tolerable resistance to the transmission of heat. Since the dirt is assumed to have no packing effect in the analysis, the value of the transient resistance $R\theta$ is

$$\text{Rate of Removal} = K_2 \tau\, x_\theta \qquad (6)$$

where K_2 is also arbitrary and x_θ is the thickness of the dirt. The change in the film thickness with time is then:

$$\frac{dx_\theta}{d\theta} = K_1 c' W - K_2 \tau x_\theta \qquad (7)$$

$$\tau = \frac{2^{(3-2a)}}{\pi^{(2-a)}} \cdot \frac{K_f}{g} \cdot \frac{W^{(2-a)}}{\rho} \cdot \frac{\mu^a}{(D-2x_\theta)^{(4-a)}} \qquad (8)$$

Combining Eqs. 7 & 8 and rearranging for integration:

$$\text{Let } M = K_1 c' W;\ N = \frac{2^{(3-2a)}}{\pi^{(2-a)}} \cdot \frac{K_f K_2}{g} \cdot \frac{\mu^a W^{(2-a)}}{\rho}$$

$$\theta = \int_0^{x_\theta} \frac{dx_\theta}{M - N\dfrac{x_\theta}{(D-2x_\theta)^{(4-a)}}} \qquad (9)$$

The integrand converges for $\left[\frac{N}{M} \cdot \frac{x_\theta}{(D-2x_\theta)^{(4-a)}}\right] < 1$

or the rate of deposition exceeds the rate of removal at all times. Rewriting Eq. (9) one obtains:

$$\theta = \frac{1}{M} \int_0^{x_\theta} \left\{1 + \frac{N}{M} \cdot \frac{x_\theta}{(D-2x_\theta)^{(4-a)}} + \left[\frac{N}{M} \cdot \frac{x_\theta}{(D-2x_\theta)^{(4-a)}}\right]^2 + \ldots\right\} dx_\theta \qquad (10)$$

$$\frac{d(\Delta p)}{d\theta} = \frac{4L}{(D-2x_\theta)} \left\{\frac{2^{(4-2a)}}{\pi^{(2-a)}} \cdot \frac{(4-a)}{g\rho} \cdot \frac{K_f}{(D-2x_\theta)^{(5-a)}} \cdot \frac{\mu^a}{} \cdot \frac{W^{(2-a)}}{}\right\} \left\{K_1 c' W - \frac{2^{(3-2a)}}{\pi^{(2-a)}} \cdot \frac{K_f K_2}{g\rho} \cdot \frac{\mu^a}{(D-2x_\theta)^{(4-a)}} \cdot \frac{W^{(2-a)} x_\theta}{}\right\} \qquad (11)$$

$$\frac{x_\theta^*}{(D-2x_\theta^*)^{(4-a)}} = \frac{M}{N} \qquad (12)$$

NOMENCLATURE

A = Heat transfer surface based on tube O.D., ft.²
a = Exponent
B = Constant
c = Constant
c' = Dirt concentration consistent with K_1
D = Tube inside diameter, ft.
f = friction factor, dimensionless
g = Gravitational constant, ft./hr.²
K_1, K_2 = Constants
K_f = Blasius constant
L = Total tube length, ft.
M, N = Substitution terms
ΔP = Pressure drop, lb./ft.²
$\Delta P^*_1, \Delta P^*_2$ = Comparative values of the pressure drop, lb./ft.²
Q = Heat flow, Btu./hr.
Q_θ = Heat already delivered, Btu.
R = Transient fouling resistance, hr. x ft.²x °F/Btu.
U = Over-all heat transfer coefficient, Btu./hr. x ft.² x °F
V = Velocity, ft./hr.
W = Constant weight flow, lb./hr.
x = Thickness of a dirt film, ft.
x^*_1, x^*_2 = Comparative values of the dirt film thickness, ft.

Greek

Θ = Time, hr.
μ = Viscosity
ρ = Density, lb./ft.³
τ = Shear stress, lb./ft.²

Subscripts

$_0$ = Time zero
$_\theta$ = Finite time

Superscript

* = Characteristic of the asymptote

directly related to the transient dirt thickness x_θ by the constant value of the thermal conductivity of the dirt. An asterisk will be used to indicate the characteristics of the variables at the asymptote. Consider now the energy requirements to reduce the height of x_θ^* so that the apparatus may operate continuously dirty. The asymoptotic dirt film thickness x_θ^* in Eq. 11 is given by: (See Eq. 12, bottom, page 72.)

The value of the pressure drop at the asymptote is given by: (See Eqs. 13 and 14, bottom, page 73.)

Combining Eqs. 12, 13, and 14 and replacing M by its components: (See Eq. 15, bottom, page 73.)

Since a is generally less than 0.25 the expression can be simplified by taking the value of $a = 0$. Eq. 15 then becomes: (See Eq. 16, pg. 73.)

One can estimate the influence of the variables by taking the ratio of the asymptote for the same fluid under two different operating conditions. The ratio becomes: (See Eq. 17, bottom, page 73.)

EXAMPLES

In a recent article (3) the authors described a common occurrence in plant operation. The figures are somewhat exaggerated to demonstrate the point. A light-ends overhead condenser condenses a vapor from 130° to 100°F using cooling tower or surface water operating from 85° to 100°F. A substantial part of the condensate returns to the column as reflux. A cold climatic spell develops, dropping the inlet temperature of the water to 55°F. Assuming the same approach as before, the outlet temperature of the condensate drops from 100° to 70°F. The demand on the reboiler utilities increases while the separation of the overhead product falls off because the subcooled condensate nullifies the vapor-liquid equilibria on several of the upper trays of the column. To bring the condensate temperature back to 100°F the water is throttled to provide a range from 55° to 100°F.

Previously, with a 15°F. range the water flowed at a design linear velocity of, say, 3 fps. With a range of 45°F in cold weather the linear velocity has been reduced to 1 fps. After a relatively brief period of operation under these conditions the condensate rises above the 100°F outlet. A gradual increase in the water flow rate fails to produce any visible effect. In the light of Eq. (17) if the condenser were performing at 3 fps at an asymptotic dirt level such that it created no cleaning problem, what quantitative effect did throttling have?

The length of path remains the same and, using the subscript 1 for the original condition, $L_2 = L_1$. Since flow has been cut to one-third, the pressure drop at the asymptote has dropped approximately to one-tenth so that $\Delta P^*_1/\Delta P^*_2 = 10$. The amount of dirt brought into the system is represented by the weight flows and so $W_1/W_2 = 3$. Equation 17 then becomes: (See Eq. 18, bottom, page 73.)

If the water and condensation coefficients are relatively high, the throttling action can convert the asymptotic dirt layer into the controlling resistance.

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$$\Delta \rho^*_\theta = \frac{4 L \tau^*}{(D - 2x^*_\theta)} \qquad (13)$$ From Eq. (8)

$$\tau^*_\theta = \frac{N}{K_2 (D - 2x^*_\theta)^{(4-a)}} \qquad (14)$$

$$(x^*_\theta)^{5-a} = \frac{32\, \pi^{(2-a)}\, g \rho\, L^{(4-a)}\, K_1^{(5-a)}\, c'^{(5-a)}\, W^3}{K_f\, \mu^a\, K_2^{(5-a)}\, (\Delta P^*_\theta)^{(4-a)}} \qquad (15)$$

$$x^*_\theta = \frac{2K_1 c'}{K_2} \left(\frac{\pi^2\, g \rho\, L^4\, W^2}{K_f \rho (\Delta P^*_\theta)^4} \right)^{1/4} \qquad (16)$$

$$\frac{(x^*_\theta)_2}{(x^*_\theta)_1} = \left(\frac{L_2}{L_1}\right)^{0.8} \left(\frac{(\Delta P^*_\theta)_1}{(\Delta P^*_\theta)_2}\right)^{0.8} \left(\frac{W_2}{W_1}\right)^{0.6} \qquad (17)$$

$$x^*_2 = \left(\frac{1}{1}\right)^{0.8} \left(\frac{10}{1}\right)^{0.8} \left(\frac{1}{3}\right)^{0.6} = 3.28\, x^*_1 \qquad (18)$$

Field performance testing of Air cooled heat transfer equipment

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IN FIELD performance testing of air-cooled heat transfer equipment, there appears to be a decided lack of uniformity in test procedure and, consequently, in the test results. Field testing of air-cooled heat transfer equipment is difficult even under good conditions, and good conditions rarely exist. Frequently there is not a sufficient length of straight pipe in which to install a pitot tube or other measuring device for determination of the tube side flow rates. As a result, mainly of having to make approximations of the tube side data, heat balances of 10 to 25 percent on this type of equipment have been common and even expected in a field test. Test procedure described herein gives much better heat balances.

A standard test procedure should be developed. It should be based on air side data with tube side data used for "check" purposes only. Heat balances obtained in the test cited in this paper will show, air side data can be obtained with good accuracy. Moreover, portable instruments suitable for doing a good job of measuring air side data are cheap by comparison to the cost of installing tube side flow measuring equipment on each air-cooled unit. Furthermore, the specific heat and physical properties of air are well known.

A standard test procedure should designate the over-all transfer rate as the criterion for judging acceptability of an exchanger. In evaluating the performance of an air-cooled exchanger in which there is little or no phase change, it is our practice to calculate the design inside or outside transfer rates, whichever appears easiest. Then using the design over-all transfer rate, the other value is obtained. The design inside transfer rate is then multiplied by the ratio of the actual tube side flow rate existing during the test to the design flow rate raised to the 0.8 power. This manipulation yields the inside transfer rate to test conditions which is recombined with design outside transfer rate to give the design over-all transfer rate corrected for actual flow conditions. The overall transfer rate determined by the test is expected to exceed this corrected overall rate. We are interested in fan performance only when the unit does not meet the design over-all rate. The manufacturer should be as much responsible for providing adequately sized fans and drivers as it is to furnish sufficient surface.

The question always arises as to whether a new unit should be expected to meet the design "clean" over-all rate or the design "foul" over-all rate. If there is reason to suspect that the unit is fouled, it is cleaned immediately prior to the performance test and the over-all transfer rate is expected to be somewhat higher than the design fouled rate. There is no set policy as to how much higher it should be. This is a matter which a standard test procedure should clearly define.

In new plants all types of equipment are tested soon after being put into operation. This is done as a standard part of the construction section's job. Several cases of severely malfunctioning equipment have been found. These initial tests later serve as a useful reference point for diagnosing problems of operation.

Another reason for testing the equipment is that most manufacturers guarantee their workmanship and materials for a period of one year. There-

General view of engine jacket water coolers after conversion to round fin-tube type bundles.

fore, the equipment is tested within the guaranty period and the results are extrapolated to design conditions. The manufacturer is notified if the test indicates the equipment will not meet the specifications on which it was purchased. Usually the manufacturer sends a representative to witness a retest of the unit.

Tests are also run to determine the need for additional equipment or to determine when and what maintenance is required.

The test procedure and equipment to be described were used to test a hybrid exchanger in which radiator type cores were replaced with round finned tubes. In making the change, two new tube bundles in parallel were used. Each new bundle was single pass and consisted of 215⅝ in. O.D., 20 BWG, phosphorus inhibited admiralty tubes. The tubes are 17 ft. 9 in. long with 9⅝ in. high extruded aluminum fins per inch. Tube spacing is 1-9/16 in. square pitch, four rows deep with the top row staggered. Each bundle is 7 ft. 2 in. wide with a box type header at each end. The unit is an induced draft type, utilizing 12 ft. diameter, steel blade, De Bothezat fan, driven by a 5-15 horsepower, two-speed, electric motor through a right angle reduction gear. At the time this unit was tested, it had been in service about six months.

In general, the test procedure consisted of getting the water rate constant by "locking in" the automatic control valve and maintaining the engine load constant. Then temperatures were taken, air and water velocities were measured, and temperatures taken again. Temperatures used are the average of the two readings.

All temperatures were measured with iron-constantan thermocouples using a Leeds-Northrup, Model No. 8662, manual balance portable potentiometer.

Water temperatures in and out were obtained from thermocouples in stainless steel thermometer wells located in the piping. The wells were filled with oil. Thermocouples for measuring ambient air temperatures were suspended approximately 18 in. below the tube bundle on the outside periphery of the unit. This location was chosen so that the temperature of re-circulation air, as well as of ambient air, would be measured.

To get exhaust air temperatures, the unit was shut down during the cool morning hours and thermocouples were placed in approximately equal areas of the top surface of the tube bundles, and supported 8 in. above the bundles. Air flow rate was obtained by measuring air velocity with a Taylor Instrument Company, Model 3132, 4 in. diameter, revolving vane anemometer. Face area of the tube bundles was divided into 16 equal areas, each approximately 3⅛ x 4⅛ ft. Readings of 30 seconds duration were taken in each area. The anemometer was held approximately 2 in. from the face of the tube bundle and moved slowly and uniformly over the area. Anemometer calibration factors were applied to each reading taken.

Water flow rate was measured in two ways. One way was by pressure drop through the cooler, using a mercury manometer. Pressure taps were in the plug sheets on each header box at the opposite ends of the same tube. The second method of obtaining water rate was to measure the water velocity by a single plane pitot tube traverse in each of the 6 in. inlet water lines. Impact and static pressure differences were measured with an American Meter Company 20 in. bellow type flow meter.

Table 1 shows the calculated results of the four test runs. In calculating water rate from the pressure drop measurement, the friction factor curve shown in D. Q. Kern's book *Process Heat Transfer* was used in conjunction with the tube entrance and exist loss curve shown in Scovill's *Heat Exchanger Tube Manual*.

In the four runs, heat balances varied from about 1.5 to 10.6% of the air side heat load.

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Table 1. Summary of calculated results

	Run #1	Run #2	Run #3	Run #4
Air Side				
Avg. Temp. In °F	98.2	94.8	91.9	89.6
Avg. Temp. Out °F	145.8	143.6	144.9	143.3
Temp. Air °F	47.6	48.8	53.0	53.7
Avg. Air Velocity @ Amb. Cond. Ft./Min.	558	555	551	558
Air Flow Rate (14.65 & 60°F) SCFM	106,600	106,700	106,500	108,300
Air Side Heat Load MM Btu/Hr.	5.50	5.74	6.22	6.41
Water Side				
Avg. Temp. In °F	164.5	162.8	167.7	163.9
Avg. Temp. Out °F	155.9	154.4	156.7	154.6
Temp. Water °F	8.6	8.4	11.0	9.3
Water Rate (Pitot) lb./Hr.	640,900	642,000	633,200	634,200
Water Rate (Press. Drop) lb./Hr.	640,800	646,200	636,000	640,800
% Difference %	.015	.65	.44	1.035
Water Side Heat Load (Pitot) MM Btu/Hr.	5.51	5.39	6.96	5.90
Heat Balance (Pitot Water Rate Heat Load Difference as % of Air Side)	1.45	6.52	10.6	8.64
LMTD (Corr. Fact) Both Fluids unmixed	.98	.97	.96	.98
LMTD (Corr.) °F	33.9	34.5	39.0	37.9
Overall Transfer Rate Based on Air Side Heat Load Btu/Hr.-Ft.² °F	134	135	129.6	137.5
Average		134		
% Deviation from Avg.	0	.74	-3.2	2.6
Based on Water Side Heat Load Btu/Hr.-Ft.² °F	132	127	142	127
Average		132		
% Deviation from Avg.	0	-3.8	7.6	-3.8

Kinetic analysis of Naphtha reforming with platinum catalyst

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Here is a simplified calculation method which makes possible the selection of operating conditions, the number of reactors with intermediate reheaters, and catalyst bed sizes for commercial reactor systems. Calculations, made with this method, are said by the author to have given excellent agreement with actual operations from several commercial units.

Four major reactions occur in reforming petroleum naphtha over platinum catalyst:

1. naphthenes $\rightleftarrows$ aromatics + $3H_2$
2. paraffins $\rightleftarrows$ naphthenes + H_2
3. hydrocracking of naphthenes
4. hydrocracking of paraffins

The complex naphtha mixture is idealized so that each of the three hydrocarbon classes—paraffins, naphthenes, and aromatics—is represented by a single compound having the average properties of that class. With this simplified model, a kinetic analysis is developed which describes the reforming operation with satisfactory accuracy.

The justification for these simplifying assumptions is in the nature of the reactions which form products having the same number of carbon atoms as the precursors. For example:

heptane $\rightleftarrows$ methylcyclohexane $\rightleftarrows$ toluene
octane $\rightleftarrows$ dimethycyclohexane $\rightleftarrows$ xylene

There is some disproportionation caused by the hydrocracking reaction, but this shows up mainly in the pentane and lighter fraction. Only small quantities of benzene are produced from naphtha feeds which consist of C_7H_x to $C_{10}H_x$ hydrocarbons.

It is reasonable to assume that each of the three hydrocarbon classes has the same number of carbon atoms. The molecular weight of each class is obtained from the average molecular weight of the feed.

$$N_P(MW)_P + N_N(MW)_N + N_A(MW)_A = (MW)_F$$

or expressing molecular weight in terms of molecular formula

$$N_P(C_nH_{2n+2}) + N_N(C_nH_{2n}) + N_A(C_nH_{2n-6}) = (MW)_F$$

and since the number of carbon atoms in each class is equal,

$$n = \frac{1}{14}(MW_F - 2N_P + 6N_A)$$

Reaction rates

Although the chemical reactions under discussion are heterogeneously catalyzed, satisfactory correlations are obtained if the system is treated as though it were homogeneous. For the homogeneous reaction

$$aA + bB \rightleftarrows qQ + rR$$

the rate in a constant volume operation, as proposed by Guldberg and Waage (*1*), is:

$$-\frac{dC_A}{d\theta} = kC_A^a C_B^b$$

For the general case,

$$\frac{1}{V}\frac{dN_A}{d\theta} = \frac{1}{V}\frac{d(C_AV)}{d\theta}$$

$$= k'_f C_A^a C_B^b - k'_r C_Q^q C_R^r \qquad (A)$$

It is readily seen that equation (A) reduces to that of Guldberg and Waage if the volume is constant and the reverse reaction is ignored. In a flowing system, the velocity at any point is $V/A = dx/d\theta$ *and* $dV_R' = AdX = Vd\theta$ (*2*). If the ideal gas law holds,

$$C_A = \frac{N_A}{V} = \frac{p_A}{RT}.$$

Therefore, for a flowing system, equation (B) holds.

$$\frac{dN_A}{dV_R'} = k'_f C_A^a C_B^b - k'_r C_Q^q C_R^r$$

$$= k_f p_A^a p_A^b - k_r p_Q^q p_R^r \qquad (B)$$

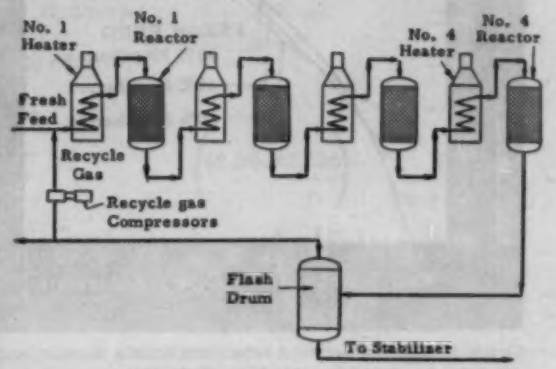

Figure 3. Flow sheet of typical reforming process using four reactors.

For the practical application of the equations involved in this study, it is convenient to express the reactor volume, V_R', as reciprocal space velocity or pounds of catalyst per mole of fresh feed per hour and N as moles per mole of fresh feed.

For the reaction

naphthene (1 mole) $\rightleftarrows$ aromatic (1 mole) + $3H_2$ the forward reaction rate = $k_f p_N$, and the reverse reaction rate = $k_r p_A p_{H_2}^3$.

The net forward reaction rate is

$$-\frac{dN_N}{dV_R} = k_f p_N - k_r p_A p_{H_2}^3$$

At equilibrium $k_f p_N = k_r p_A p_{H_2}^3$, and the equilibrium constant is

$$K_p = \frac{k_f}{k_r} = \frac{p_A p_{H_2}^3}{p_N}$$

Substituting and rearranging, the net forward reaction rate is

$$\frac{-dN_N}{dV_R} = \frac{k_f}{K_p} p_N \left(K_p - \frac{p_A p_{H_2}^3}{p_N} \right)$$

Similarly, for the reaction

naphthenes (1 mole) + H_2 $\rightleftarrows$ paraffins (1 mole)

the equilibrium constant is

$$K_p = \frac{k_f}{K_r} = \frac{p_p}{p_N p_{H_2}}$$

and the net forward rate is

$$\frac{-dN_N}{dV_R} = \frac{k_f}{K_p} p_N p_{H_2} \left(K_p - \frac{p_p}{p_N p_{H_2}} \right)$$

Hydrocracking

Experimental data show that methane, ethane, propane, butane, and pentane are produced in approximately equal molal proportions in the hydrocracking reaction. Therefore, for the hydrocracking of paraffins the stoichiometric balance is as in (C).

$$C_n H_{2n+2} + \left(\frac{n-3}{3}\right) H_2 \rightarrow \frac{n}{15} C_1 + \frac{n}{15} C_2 + \frac{n}{15} C_3 + \frac{n}{15} C_4 + \frac{n}{15} C_5 \qquad (C)$$

The first-order reaction rate

$$\frac{-dN_P}{dV_R} = \frac{k_C}{\pi} p_P$$

suitably fits the data.

The stoichiometric balance for the hydrocracking of naphthenes is as in (D).

$$C_n H_{2n} + \frac{n}{3} H_2 \rightarrow \frac{n}{15} C_1 + \frac{n}{15} C_2 + \frac{n}{15} C_3 + \frac{n}{15} C_4 + \frac{n}{15} C_5 \qquad (D)$$

and the first-order reaction

$$\frac{-dN_N}{dV_R} = \frac{k_C}{\pi} p_N$$

suitably fits the data.

Heats of reaction

Heats of reaction are nearly independent of the component molecular weight over the range normally encountered in reforming when based on the hydrogen entering into the reaction.

An enthalpy balance gives the temperature change for an adiabatic system:

$$dN_{N \rightarrow P} \Delta H_{N \rightarrow P} + dN_{N \rightarrow A} \Delta H_{N \rightarrow A} + dN_{PC} \Delta H_{PC} + dN_{NC} \Delta H_{NC} = N_T C_P dT$$

dividing by dV_R and rearranging

$$\frac{dN_{N \rightarrow P}}{dV_R} \frac{\Delta H_{N \rightarrow P}}{N_T C_P} + \frac{dN_{N \rightarrow A}}{dV_R} \frac{\Delta H_{N \rightarrow A}}{N_T C_P} + \frac{dN_{PC}}{dV_R} \frac{\Delta H_{PC}}{N_T C_P} + \frac{dN_{NC}}{dV_R} \frac{\Delta H_{NC}}{N_T C_P} = \frac{dT}{dV_R}$$

Equilibrium and reaction rate constants

The equilibrium and reaction rate constants were determined from data obtained from reforming runs over extreme ranges of space velocity with Sinclair-Baker platinum catalyst of virgin activity.

SUMMARY

a). Conversion of naphthenes to aromatics.

$$\text{naphthene} \rightleftarrows \text{aromatic} + 3\,H_2$$

Equilibrium constant $K_p = \dfrac{p_A p_{H_2}^3}{p_N}$;

$$K_p = e^{\left(46.15 - \frac{46{,}045}{T}\right)} \text{ atm.}^3$$

continued

Naphtha reforming

continued

Rate equation $-\frac{dN_N}{dV_R} = \frac{k_f}{K_p} p_N \left(K_p - \frac{p_A p_{H_2}^3}{p_N} \right)$;

$k_f = e^{\left(23.21 - \frac{34{,}750}{T}\right)}$, $\frac{\text{moles}}{\text{(hr.) (lb. cat.) (atm.)}}$

Heat of reaction = 30,500 Btu./mole of H_2 liberated (3) (endothermic).

Rate of temperature change

$$\frac{dT}{dV_R} = \frac{dN_N}{dV_R} \frac{(91{,}500)}{N_T C_P}$$

b.) Conversion of naphthenes to paraffins.

naphthene + $H_2 \rightleftarrows$ paraffin

Equilibrium constant

$$K_p = \frac{p_P}{p_N p_{H_2}}; \quad K_p = e^{\left(\frac{8000}{T} - 7.12\right)}, \text{ atm.}^{-1}$$

Rate equation

$$-\frac{dN_N}{dV_R} = \frac{k_f}{K_p} p_N p_{H_2} \left(K_p - \frac{p_P}{p_N p_{H_2}} \right);$$

$$k_f = e^{\left(35.98 - \frac{59{,}600}{T}\right)}, \frac{\text{moles}}{\text{(hr.) (lb.cat.) (atm.)}}$$

Heat of reaction = −19,000 Btu./mole of H_2 consumed (3), (exothermic).

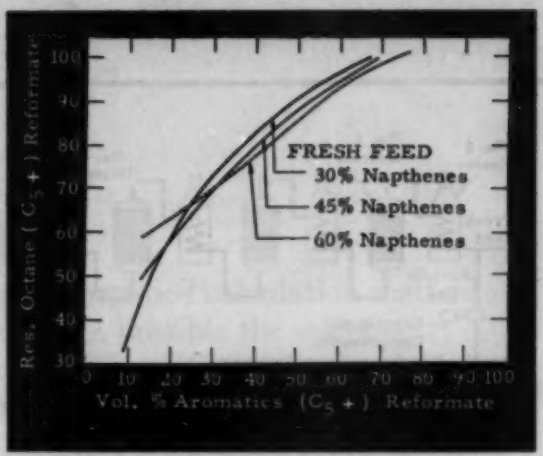

Figure 1. Relation between reformate octane number and aromatic concentration for three feedstocks.

Rate of temperature change

$$\frac{dT}{dV_R} = \frac{dN_N}{dV_R} \frac{(-19{,}000)}{N_T C_P}$$

c.) Hydrocracking of paraffins

Rate equation $-\frac{dN_P}{dV_R} = \frac{k_C}{\pi} p_P$;

$$k_C = e^{\left(42.97 - \frac{62{,}300}{T}\right)}, \frac{\text{moles}}{\text{(hr.) (lb.cat.)}}$$

Heat of reaction = −24,300 Btu./mole of H_2 consumed (3), (exothermic).

Table 1. Feedstock analysis and operating conditions.

	Feedstock
Gravity, °API	54.3
ASTM Distillation	
IBP	182°F.
10%	238
50%	264
90%	310
EP	356
Mol wt.	114.8

Feedstock components (Basis = 100 bbl.)

Components	Mole %	Molecular Weight	Pounds	Moles	Moles/Bbl.	Bbl.
Paraffins	31.0	$C_{8.2}H_{18.4}$ = 116.8	8,410	72.0	2.19	32.9
Naphthenes	58.3	$C_{8.2}H_{16.4}$ = 114.8	15,544	135.4	2.33	58.4
Aromatics	10.7	$C_{8.2}H_{10.4}$ = 108.8	2,709	24.9	2.86	8.7
	100.0	(114.8)	26,663	232.3	(2.32)	100.0

Operating Conditions

	Rctr. 1	Rctr. 2	Rctr. 3	Rctr. 4
Catalyst Distribution	1	1	2.75	3.5
WHSV (overall WHSV = 2.75)	22.69	22.69	8.25	6.48
MHSV	0.198	0.198	0.072	0.056
Reactor inlet temperature, °F.	943	943	943	943
Reactor pressure, lb./sq. in. abs.	586	580	575	560
Recycle ratio, moles/mole fresh feed	6.9			
Mole % H_2 in recycle	85.3			
Recycle mol. wt.	6.0			
Flash drum pressure lb./sq. in. abs.	515			
Flash drum temperature, °F.	100			

Rate of temperature change

$$\frac{dT}{dV_R} = \frac{dN_P}{dV_R} \frac{(-24{,}300)\left(\frac{n-3}{3}\right)}{N_T C_P}$$

d.) Hydrocracking of naphthenes.

Rate equation $-\frac{dN_N}{dV_R} = \frac{k_0}{\pi} p_N$;

$$k_0 = e^{\left(42.97 - \frac{62{,}300}{T}\right)} \quad \frac{\text{moles}}{(\text{hr.})(\text{lb. cat.})}$$

Heat of reaction = −22,300 Btu./mole of H_2 consumed (3), (exothermic).

Rate of temperature change

$$\frac{dT}{dV_R} = \frac{dN_N}{dV_R} \frac{(-22{,}300)\frac{n}{3}}{N_T C_P}$$

The hydrocracking rate of the aromatics is extremely slow and, therefore, is disregarded.

Octane number of reformate

The object of naphtha reforming generally is to increase the octane number of motor fuel. Since the octane number of the aromatics in the reformate ranges between 120 to 140 and the paraffins between 40 and 60, a simple relationship exists between the reformate octane number and the aromatic concentration for any

continued

Table 2. Calculated results and comparison with commercial run.
Calculation Basis = 100 bbl. of fresh feed

	Calculated Results				Results of Commercial Run			
Overall WHSV	2.75				2.75			
Reactor numbers	1	2	3	4	1	2	3	4
Cat. distribution	1	1	2.75	3.5	1	1	2.75	3.5
Individual Reactor Results								
WHSV	22.69	22.69	8.25	6.48	22.69	22.69	8.25	6.48
Inlet temp., °F.	943	943	943	943	952	952	957	952
Outlet temp., °F.	817	858	908	949	823	881	912	939
Temp. drop., °F.	126	85	35	−6	129	71	45	13
Moles (C_6+) paraffins lv. reactor	76.0	79.2	75.0	42.5	.....	.....	.....	.....
Moles (C_6+) naphthenes lv. reactor	80.0	39.6	12.7	4.9	.....	.....	.....	.....
Moles aromatics leaving reactor	74.7	109.5	129.4	140.1	.....	.....	.....	.....
Total moles (C_6+) leaving reactor	230.7	228.3	217.1	187.5	.....	.....	.....	.....

Overall results		
Total reactor temp. drop, °F.	240	258
Yields : *moles*		
H_2	252.5	279.6 moles/100 bbl. fd.
C_1	24.5	
C_2	24.5	
C_3	24.5	
iC_4	12.2(1)	
nC_4	12.2(1)	
iC_5	16.3(2)	
nC_5	8.2(2)	
(C_6+) Paraffins	42.5	
Naphthenes	4.9	
Aromatics	140.1	
Total moles	562.5	
Barrels		2.5(C_4's)
iC_5	5.4	2.5
nC_5	2.7	1.6
(C_6+) Paraffins	19.4	21.3
Naphthenes	2.1	2.0
Aromatics	49.9	51.3
Total bbl. C_5—EP (vol. % yield)	79.5	81.2
Octane		
Vol. % aromatics in C_5—EP reformate	62.8	63.2
Reformate rsch. octane, clear (Figure 1)	95.4	95.5

(1) Moles of iC_4 = ½ moles total C_4's
(2) Moles of iC_5 = ½ moles total C_5's

Naphtha reforming

continued

given feedstock composition. This relationship for three different feedstocks is shown in Figure 1.

Example

For the purpose of illustration the results of an actual operation are compared with the results calculated by this method for the same reactor system. The feedstock analysis and operating conditions are presented in Table 1. The naphtha feed is characterized by the ASTM distillation, gravity, molecular weight, and the paraffin-naphthene-aromatic analysis.

Calculations are made with this method by judicious choice of increments. Molal and enthalpy balances are made across each increment with the rate and equilibrium constants chosen for the average temperature of the increment. It is obvious that the accuracy improves with the number of increments used. The example calculations were made on an IBM 650 digital computer using a program developed from this method and with approximately 100 increments per reactor. The results of the computer calculations are shown in Table 2 and Figure 2. The comparison of the calculated results with the results of the commercial run is also included in Table 2.

It may be noted that the required reactor inlet temperatures for the calculation are lower than the temperatures recorded from the commercial run for the same product octane. The equilibrium and rate constants presented herein are based on virgin catalyst. In the commercial run, the catalyst in the reactors was not fresh and some deactivation had occurred. The temperature requirement for the calculation is lower than that for the commercial run because of the deactivation of the catalyst in the commercial reactors. The effect of activity decline on the temperature requirement can be evaluated by the method of Smith and Dresser(4).

Some interesting observations can be made from Figure 2, which shows temperature profiles calculated for the four adiabatic reactors. The large temperature drop in the first and second reactors shows that dehydrogenation is the predominant reaction, since the dehydrogenation is endothermic. In the third reactor, although there is a net temperature drop across the catalyst bed, substantial hydrocracking of naphthenes and paraffins is indicated by the positive slope of the right-hand portion of the temperature profile. Hydrocracking occurs to a larger extent in the fourth reactor.

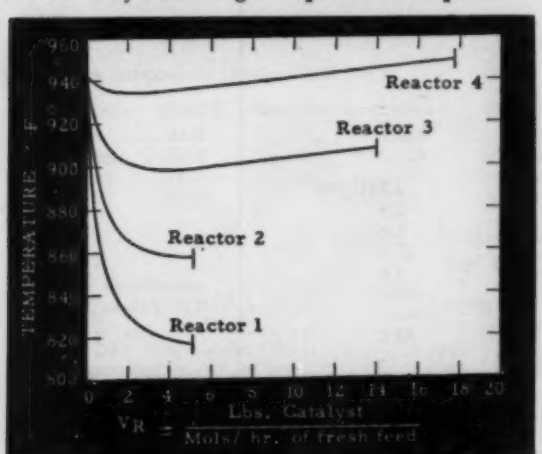

Figure 2. Results of the IBM 650 calculations made in the above example application of the method.

With the calculation method presented, it is possible to select operating conditions, the number of reactors with intermediate reheaters, and catalyst bed sizes for commercial reactor systems. Calculations with this method have given excellent agreement with actual operations from many commercial units.

NOTATION

A	=	cross section area of reactor
C	=	concentration, moles per unit volume
C_p	=	molal specific heat Btu./mole °F.
ΔH	=	heat of reaction, Btu./mole
k	=	rate constant
k_c	=	rate constant for hydrocracking reaction
k_f	=	rate constant for forward reaction
k_r	=	rate constant for reverse reaction
K_p	=	equilibrium constant
N	=	moles per mole of fresh feed
n	=	number of carbon atoms
p	=	partial pressure, atm.
R	=	gas constant
T	=	temperature, °Rankine
V_R'	=	volume of reactor
V_R	=	reciprocal space velocity, lb. catalyst/mole of fresh feed/hr.
V	=	volume of moles in the reactor
MW	=	molecular weight
MHSV	=	$1/V_R$ = moles of fresh feed/hr./lb. of catalyst
WHSV	=	weight hourly space velocity = lb. fresh feed/hr./lb. catalyst
x	=	length of the reactor
π	=	system pressure, atm.
θ	=	time

SUBSCRIPTS

A	=	aromatics
F	=	feed
N	=	naphthenes
P	=	paraffins
T	=	total
N→P	=	naphthene conversion to paraffins
N→A	=	naphthene conversion to aromatics
NC	=	naphthene cracking
PC	=	paraffin cracking

ACKNOWLEDGEMENTS

The constants presented in this paper were developed by H. M. Siegel, who is also credited here for his contributions to the development of the method.

The example presented was calculated by T. H. Korelitz, who is given credit here for his critical comparison of the calculated results with those from commercial plants and the application of the method for plant design.

The method was programmed for the IBM 650 computer by F. R. Dornheim and R. R. Edison.

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4. Smith, R. B., and T. Dresser, *Petroleum Refiner*, **38**, p. 199, (July, 1957).

Presented at A.I.Ch.E. Salt Lake City Meeting.

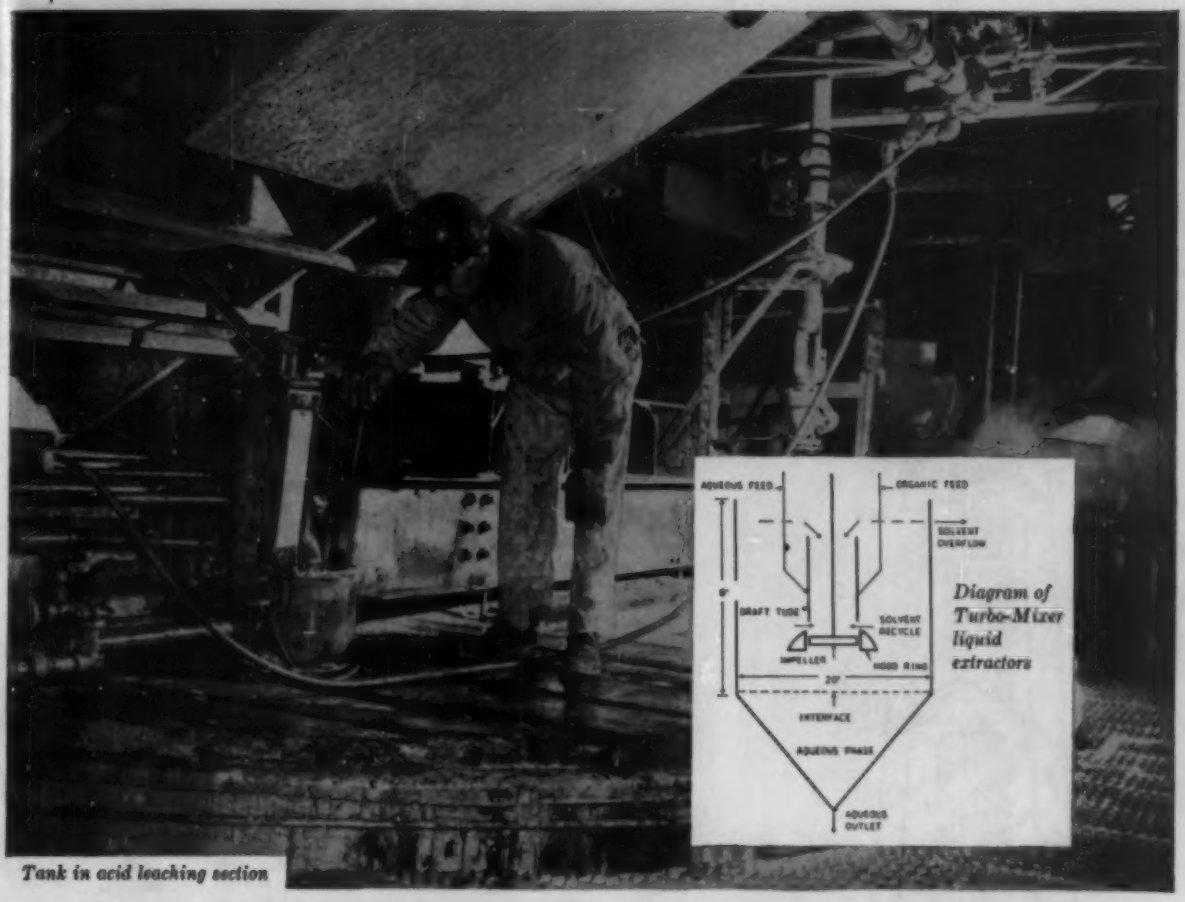

Diagram of Turbo-Mixer liquid extractors

Tank in acid leaching section

VITRO URANIUM HANDLES A WIDE VARIETY OF URANIUM MINERALS WITH TURBO ON THE JOB

When VITRO URANIUM COMPANY of Salt Lake City embarked on a modernization program, they called on GENERAL AMERICAN to assist in the design of the most modern mill possible.

Heart of the plant is the extraction system, and here, GENERAL AMERICAN Turbo-Mixers proved to be key equipment, in both the leaching and liquid extraction sections.

VITRO URANIUM processes a wide variety of uranium minerals which require highly versatile extraction equipment. GENERAL AMERICAN Turbo-Mixers fit this requirement, replacing an outmoded phosphate precipitation operation. Recoveries of uranium fed into the system are "excellent."

As a result of VITRO'S million and a half dollar modernization program, the 660 ton/day mill already has significantly reduced operating costs. Further proof that in processing as in transportation and storage, it pays to plan with GENERAL AMERICAN.

PROGRESS THROUGH BETTER TECHNOLOGY

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all corrosion

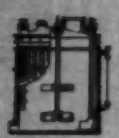
Most people think that one corrosion resistant material will control all corrosion, but nothing could be further from the truth. Each known material is either subject to attack by a given chemical or not. There is seldom any "middle ground." The unique feature of complete resistance to corrosion of the properly selected Haveg Plastic, however, provides unquestionably the most effective and ultimately the least expensive material for any given use.

The properties and performance of the various plastics are predictable and their design characteristics are intimately known to the Haveg Engineer permitting qualified recommendations for each specific application.

Haveg offers the Chemical Process Industry all materials of plastic construction, thirty years of mastery of corrosion control and eight modern plants to assure prompt delivery of all types of corrosion control equipment such as Process Tanks, Heat Exchangers, Chlorine Equipment, Towers, Absorbers, Scrubbers, Fractionating Columns, Fume Removal Equipment, Pipe and Fittings.

PHENOLIC RESIN HAVEG 31—A strong, lightweight material offering excellent thermal properties for continuous or intermittent use up to 265°F. Excellent resistance to chlorine gas (wet or dry) makes this Haveg Product ideal for all connectors, headers, chlorine coolers and brine lines.

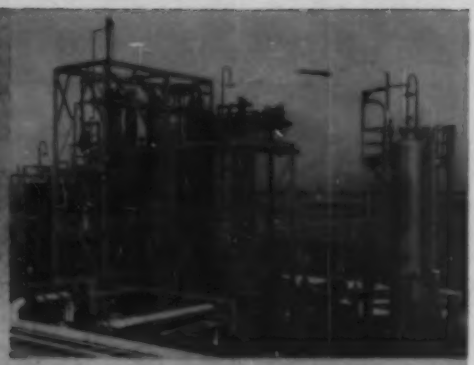
PHENOLIC RESIN HAVEG 41—Formulated to resist a wide range of acids, salts, the weaker bases and many solvents this Haveg Material offers a tough (exceptional resistance to shocks and blows) corrosion control medium which is unaffected by thermal shock or sustained temperature up to 325°F. Typical uses are process tanks, valves, fume duct, heat exchangers, towers, pipe fittings, etc.



FURANE RESIN HAVEG 61—Strong, lightweight electrically non-conductive compositions result in all standard process equipment with excellent thermal properties for use at temperatures up to 300°F. This Haveg material of construction offers excellent resistance to most alkalies, solvents, acids and salts, including hot concentrated sodium and potassium hydroxide solutions and chlorinated aromatic compounds.

POLYVINYL CHLORIDE HAVEG 1810—Haveg 1810 is unmodified PVC in rigid unplasticized form for optimum chemical resistance at most useful temperature range. Tanks, hoods, valves, dampers, fans, pipe and fittings are fabricated by Haveg Craftsmen from both normal and high impact PVC. Excellent resistance to strong, highly concentrated oxidizing agents in the low and medium temperature range at a minimum cost is the feature of Haveg 1810.

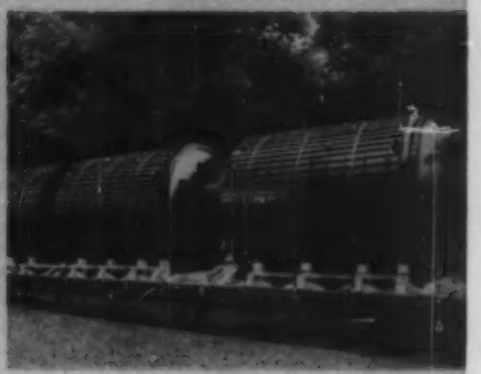
molders of control plastics



Typical of complete installations are these Haveg Towers, Heat Exchangers and Jets.

TETRAFLUOROETHYLENE HAVEG TEFLON®—Steel pipe lined with Haveg Teflon offers exceptional strength and flexibility for continuous service from —90°F to +500°F and non-sticky surface offering extremely low friction characteristics. Since Haveg Teflon Lined Steel Pipe is completely inert to virtually all chemicals, it is used for piping boiling halogenated hydrocarbons, ketones, esters, alcohols, aqua regia, hydrofluoric and nitric acids, as well as alkalies in all concentrations.

EPOXY RESIN HAVEG 93—Carbon filled epoxy Haveg 93 has been developed to withstand the corrosive action of hydrofluoric acid compounds. Recommended for continuous operating temperature up to 225°F, Haveg 93 finds extensive use in agitators, fume duct, pump parts, and holding tanks. This material has been subjected to some radiation exposure tests and indications of low level shielding has been evidenced.

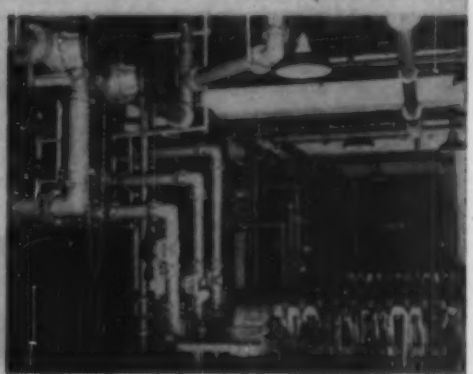


Large Haveg 41 tanks leaving Haveg Industries plant at Marshallton, Delaware.

POLYESTER GLASS HAVEG 7710—Haveg 7710 offers the broadest resistance of all polyester glass materials to corrosive chemical reagents, and solvents. Its excellent resistance to acid attack, including oxidizing medium and its broad resistance to solvents, makes this Haveg product ideal for tanks, fume hoods, duct systems, stacks, fans, blowers and towers.

POLYESTER GLASS HAVEG 7730—Featuring exceptional resistance to organic solvents, Haveg 7730 has been approved by the Food and Drug Administration and the Meat Inspection Division of the U. S. Department of Agriculture for food processing. A second big advantage of Haveg 7730 is its translucency which allows observation of liquid level in Haveg 7730 tanks without the need of special sight glasses.

POLYESTER GLASS HAVEG 7740—Haveg 7740 is a fire-resistant material of great chemical resistance particularly suitable for fume exhaust systems where a fire-resistant material is required. It is not only available as duct work but may be fabricated into hoods and exhaust fans and dampers.



Easily installed Haveg pipe provides complete corrosion resistant installation.

EPOXY GLASS HAVEG 9710—Haveg 9710 is the new epoxy-glass construction material developed by Haveg's Research Department to provide the best combination of physical, thermal and chemical-resistant properties along with characteristics which lend themselves to practical fabrication techniques.

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"Ultimate" fuel in production

Three commercial plants now turning out liquid hydrogen, fourth unit planned for West Coast.

Liquid hydrogen, with an energy content almost three times that of present fuels, is now being produced in large quantities in Ohio, California, and Florida, reveals the U.S. Air Force. Two of the plants, at Painesville, Ohio, (built and operated by Air Products), and at Bakersfield, California (built and operated by Stearns-Roger), were relatively small units designed to provide liquid hydrogen for initial testing and development purposes. The third plant, however, built and operated by Air Products in Palm Beach County, Florida, is a "tonnage" operation. Capacity, while not announced, has been surmised to be in the neighborhood of 500,000 lb./yr. Subsequent to this Air Force announcement, comes the news that the National Aeronautics and Space Administration has awarded a contract to Linde (Union Carbide) for a plant at Torrance, California. Under the terms of the contract, Linde will supply NASA up to 3,300,000 lb./yr. of liquid hydrogen.

"Large-scale availability of liquid hydrogen," said Lt. Gen. B. A. Schriever, U.S. Air Force, announcing that the large-scale Florida facilities had been in successful production for several months, "will make possible a new high-energy plateau in chemical rocket propulsion systems and vehicles." It is estimated that use of liquid hydrogen, in combination with liquid oxygen, will give an increase in thrust of about 40% over present rocket propellants.

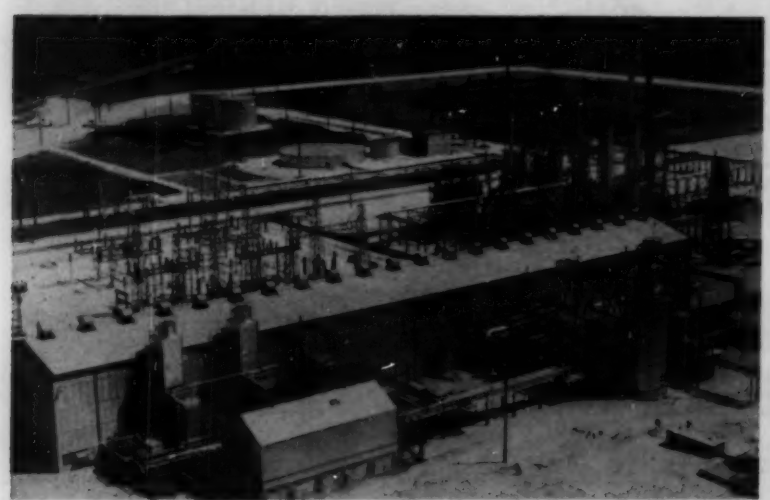
Hurdles hurdled

First serious problem was obtaining feed hydrogen of sufficient purity. In the smaller units economic use was made of by-product gas from existing chemical plants such as refinery operations or chlorine plants. For the large plant, however, the front end of a conventional ammonia plant was used. These grades of hydrogen were not satisfactory for liquefaction, and additional purification facilities were necessary.

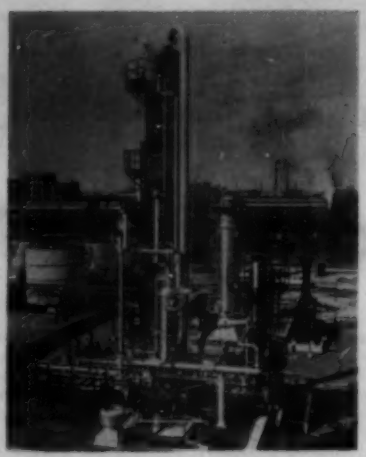
Second problem was large-scale catalytic conversion of liquid hydrogen from its unstable form (ortho) to its more stable form (para) for storage and transportation purposes.

At the Florida plant, the problem of refrigerating hydrogen down to minus 460°F for liquefaction was solved by use of newly-developed hydrogen turboexpanders.

Construction date for the Torrance, California, plant to be built by Linde are understood to have been advanced; original plans called for work to be started late this year. Impure hydrogen gas will be piped into the plant from Union Carbide Olefins' adjacent facilities at the Torrance property. Product hydrogen from the plant will contain less than 2 parts per million of impurities.



Liquid hydrogen facilities in Palm Beach County, Florida, built and operated for the Air Force by Air Products.



Overall view of new continuous tar distillation plant of Dominion Tar & Chemical, Hamilton, Ontario.

Continuous tar distillation in Canada

New plant of Dominion Tar and Chemical at Hamilton, Ontario, has capacity of 15 million gallons a year of tar, uses continuous distillation.

Said to be the first plant in Canada to use continuous techniques for tar distillation, the just-started-up Hamilton, Ontario, facilities of Dominion Tar & Chemical will use by-product coal tar from nearby steel mills to turn out wood preservatives, aromatic chemicals, coal tar pitches. This represents a radical departure from the traditional 3,500 gallon batch stills formerly standard.

In the Hamilton operation, the lighter fractions of coal tar are distilled off continuously, leaving a residue of coal tar pitch. The distillates removed contain the chemical components normally extracted. These are further fractionated to concentrate tar acids, naphthalene, and creosote.

Continuous operation

Crude tar containing one to three percent water is heated in the convection section of an oil-fired tube heater, and again in a trimming heat exchanger. It is then fed to a dehydrating column, where water and light ends in the benzene, toluene, xylene range are removed as overhead. Dry tar from the bottom of the dehydrating columns is pumped back through the radiant section of the tube heater, and flashed into the bot-

continued on page 88

For more information, circle No. 110

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U.S.I. CHEMICAL NEWS

June ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1959

Growing Market Is Seen For Phosphoric Acid as Fertilizer Raw Material

In a recent article in Farm Chemicals Magazine, Lawrence Byck — U.S.I. Manager of Heavy Chemical Sales — discusses the value of wet-process phosphoric acid as an agricultural chemical raw material. Phosphatic Fertilizer Solution (PFS) has been an intermediate in triple superphosphate production for many years, but its use as a raw material for fertilizer generally dates back only to 1957.

According to Mr. Byck, the usefulness of PFS depends on these factors:

(1) It is the only commercial source of P_2O_5 in liquid form. Dusting and massive solids handling problems are eliminated.

(2) It is by far the most highly acid source of P_2O_5 commercially available.

(3) It is the most concentrated commercial source of P_2O_5 — 52-54%.

(4) It may or may not be a markedly economical source of P_2O_5, depending on consumer location.

Given these factors, says Mr. Byck, here are some of the things PFS can do for the mixed fertilizer industry:

• Neutralize large quantities of ammonia, because of high

MORE

New Commercial Route to Copper Strip Starts with Ammonia Leaching of Scrap

Copper strip can now be made commercially from a powder which is derived from copper scrap by chemical means. Scrap is leached with ammonia, and reduced to copper powder with hydrogen gas at 375° F and 1,200 psi.

Via a specially developed process and related equipment, the powder is roll-compacted into strip that is sintered at 50-100°F below its m.p. under a hydrogen atmosphere. The strip is then rolled and annealed to specification.

Sodium Addition Improves Properties of Alloy

Recent tests have indicated that metallic sodium, added in small quantities to aluminum 356, improves ductility and the already fine mechanical properties of this casting alloy. As little as 0.02 to 0.04% seems to do the job. Above about 0.04%, additional sodium causes fluidity loss and increased porosity, with an accompanying loss of mechanical properties.

Aluminum 356, used extensively in industrial, aircraft and missile service, contains about 7% silicon and 0.3% magnesium. The silicon crystals are large and needle-shaped, which tends to make the structure relatively brittle. Sodium refines the crystals to a small, finely dispersed form to improve alloy properties.

In the tests, sodium bricks were added by immersing them in the molten alloy wrapped in aluminum foil. The foil gradually melts and allows the sodium below the surface of the molten alloy, to do its work.

Missiles and Rockets, Fast Growing Market for Chemical Materials and Research

Propellents, Lubricants, Plastics, Nonferrous Metals Among Materials Researched, Developed and Supplied by the CPI.

It is estimated that more than 25% of the $4-billion-plus government expenditure for missiles and rockets, in the fiscal year just ending, went to the chemical industry for materials, research and development. For the fiscal year starting July 1, total government expenditures for this program are expected to be about 30% greater, with the chemical industry's share possibly even higher than in 1958-1959. The U. S. space and weapons program is becoming a larger and larger factor to chemical manufacturers.

Structural Materials Largest Market

Where does the CPI fit into this vast undertaking? Structural materials are of course the greatest contribution in terms of tonnage and of dollars. Practical materials must be found to withstand temperatures as high as 7,000°F. Strength must be high. Weight must be kept down. The chemical industry is working on answers — evaluating nonferrous metals and alloys, ceramics, organic and inorganic polymers, graphites — developing new compounds, new techniques, new combinations.

Nonferrous Metals Used or Proposed For Structures in Missiles & Rockets

Aluminum	Nickel
Beryllium	Silver
Cadmium	Tantalum
Chromium	Tin
Cobalt	Titanium
Columbium	Tungsten
Copper	Zinc
Magnesium	Zirconium
Molybdenum	

Non-Metal Materials Used or Proposed For Structures in Missiles & Rockets

Alkyds	Aluminum Oxide
Epoxies	Glass
Fluorocarbons	Graphite
Phenolics	Nickel Molybdate
Polyamides	Silicon Carbide Cpds.
Polybutadienes	Thorium Oxide
Polyesters	Zirconium Boride
Polysulfides	Zirconium Oxide
Silicones	Other Ceramic Oxides
Urethanes	

Along with combinations of metals and ceramics (cermets), researchers have recently proposed metal-ceramic-plastic "alloys" which, if practical, might make the ideal rocket materials.

Propellents Greatest R&D Challenge

Propellent procurement is rather small since, of course, propellents are actually used only during firings. But the research effort in this area is enormous. The reason: none of the materials evaluated to date completely answer the requirements of the ideal propellent.

Liquid systems, on the one hand, are complex, and many of the component materials have the disadvantages of corrosiveness, toxicity, low density and, for ballistic purposes, poor storage life. However, liquids are relatively easy to control and, most important, have high specific impulse.

Solid systems, on the other hand, present problems of their own. Combustion control is difficult. Component materials need better physical properties such as flexibility and thermal expansion coefficients. Most important, they are low in specific impulse compared to liquids. But solid systems are reliable, comparatively simple equipment-wise, and can be fired easily on short notice.

In consequence, both types of systems are under intensive investigation, but with the emphasis on solids growing.

MORE

Liquid Propellent Materials, Used or Under Consideration

FUELS	OXIDIZERS
Alcohols	Chlorine Trifluoride
Alkyl Boranes	Fluorine
Amines	Hydrogen Peroxide
Aniline	Liquid Oxygen
Ammonia	Nitric Acid
Cyanogen	Nitrogen Tetroxide
Hydrazine	Oxides of Nitrogen
Hydrogen	Other
Hydrogen Cyanide	Oxygen Difluoride
Kerosene	Oxygen Fluoride
Unsymmetrical Dimethyl Hydrazine (UDMH)	Ozone
	MONOPROPELLENTS
	Ethylene Oxide
	Hydrogen Peroxide

Solid Propellent Materials, Used or Under Consideration

FUELS	
Boron Based Compounds Containing Metals Like	Polyethylenes
Aluminum	Polyurethanes
Beryllium	Polysulfide Rubbers
Magnesium	OXIDIZERS
Resins such as	Ammonium Nitrate
Acrylics	Potassium Nitrate
Butadiene-Vinyl Pyridine	Ammonium Perchlorate
Cellulosics	Potassium Perchlorate
Epoxies	Lithium Perchlorate
Phenolics	DOUBLE BASED
Polyamides	Nitrocellulose
Polyesters	Nitroglycerine

June ★ **U.S.I. CHEMICAL NEWS** ★ 1959

CONTINUED

Missiles

Many Other Types of Materials Needed

The chemical industry also supplies to the missile field materials such as lubricants, hydraulic fluids, pressurizing gases, and plastics and rubbers for seals and gaskets and protective clothing. Of particular interest is the research work in progress on synthetic lubricants to supplement the mineral-based varieties. Among the compounds under investigation are included fluorine derivatives, diester derivatives, phosphorus-boron combinations, tin-silicon compounds, silicones and alkyl silanes.

U.S.I. Contributes in Several Areas

Because of its diversified interests in chemicals, plastics and nonferrous metals, U.S.I. contributes to the vital space and weapons program both directly and indirectly. Through ⅓ ownership of Mallory-Sharon Metals, U.S.I. supplies zirconium, titanium in commercial quantities, tantalum and columbium in pilot quantities. Polyethylene, made by U.S.I., is among the resins under investigation in solid propellent fuels. Another U.S.I. product, ISOSEBACIC® acid, may be used as an intermediate for the polyurethanes studied for the same purpose, as well as for diester bases in synthetic lubricants. U.S.I. makes ethyl alcohol, long used in liquid propellent systems. AFN, Inc., 25% owned by U.S.I., has a government research contract on boron-based fuels. And in a joint venture with Food Machinery, dimethylhydrazine-type fuels are being studied.

CONTINUED

Phosphoric

acidity — an important advantage.

- Allow formulation of high-analysis grades — a strong trend in the industry — because of high concentration.
- Granular goods are growing in popularity. PFS formulations generally give more rugged granules — better suited to subsequent handling — without adding granulation aids.

In summation Mr. Byck notes that because of transportation costs, PFS will probably be uneconomical in many areas. But in many more of the important agricultural areas, it is becoming the product of choice for reasons of product quality, overall costs and adaptability to process needs.

Faster Analysis Developed For Halogens in Organics

A researcher at the Texas Agricultural Experiment Station has worked out an improved method of the quantitative determination of halogens in organic materials. It is said to be faster, cheaper than previous techniques.

In a typical analysis, the chemist would weigh a sample containing about one milliequivalent of chlorine into a beaker, add excess ammonia to dissolve and chill the sample, and ethyl ether to insure that the sample stays in solution. Chlorine is then reduced to chloride with about half a gram of metallic sodium. Appearance of a blue color indicates complete reduction, which takes only about two minutes.

Ammonia and ether are evaporated, excess sodium combines with water vapor to yield sodium hydroxide, and the blue color disappears. Nitric acid is used for neutralization, and the chloride is titrated with silver nitrate.

As little as ten minutes of the chemist's full attention is devoted to a single analysis, and several analyses can be conducted simultaneously. Error is rarely higher than 3%.

New Extraction Process Purifies Many Elements

A new extraction process for purifying a large number of elements, including many not usually subject to extraction processes, is described in USP 2,874,176 issued recently. By this technique, elements can be separated selectively from an aqueous solution containing a mixture of elements.

Here is how it works. The various elements in the solution are reacted with an alkali metal salt of perfluorocarboxylic acid. From the resulting compounds in solution, the desired compound is selectively extracted with a substantially immiscible polar organic solvent such as an alcohol, ether, ketone or phosphate.

Extraction is reported to depend on a number of variables: chain length of acid, valence of cation, organic solvent, molar ratio of cation to reagent, ion size, complexing ability of cation and pH. For example, uranyl and vanadyl ions extract together at pH 2, but at pH 1.65, only uranyl ion extracts.

After separation of the desired element, the reactions can be easily reversed so that the element is once more in aqueous phase and the reagents are recovered.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

Identification reagent for synthetic fibers, as well as for animal and vegetable fibers, can now be obtained. Claimed to give reliable identification in minutes by imparting distinct colors to different fibers. **No. 1480**

New economical corrosion inhibitor for aqueous recirculating systems combines sodium molybdate with orthophosphate. Combination claimed to be synergistic—effective as the molybdate alone but at greatly lowered cost. **No. 1481**

Automatic recording titrator now on market is designed to make variable and constant pH measurements automatically. Simultaneously provides permanent record. Titrant delivery rate and chart speed are both variable. **No. 1482**

Corrosion and spotting preventive for all metals, recently developed, is added to hot water rinses. Said to promote spot-free drying, and to leave an invisible film which protects against tarnish and corrosion for months. **No. 1483**

Volume I of new series of publications on advances in inorganic and radiochemistry can now be purchased. 449-page book contains sections on boron hydrides, lattice energies, activation analysis, phosphonitrilic halides, etc. **No. 1484**

Commercially-pure titanium anode hooks and baskets, designed to meet need for high corrosion resistance in nickel and chrome plating operations, are now on market. Said to have indefinite life in highly corrosive mixtures. **No. 1485**

Selective reductions of organic compounds with complex metal hydrides are discussed in new brochure now available. This review of published literature covers types of reactions possible, includes bibliography. **No. 1486**

Polyethylene aspirator pump now on market cannot corrode; said to perform as capably as metal aspirators, operate efficiently on all water pressures from 11 pounds up. Recommended for highly corrosive filtrates. **No. 1487**

Physical and thermodynamic properties of many commonly-used elements and compounds are covered in new brochure offered by catalyst maker, to aid in catalyst selection when factors of equilibrium, heat exchange, etc. are vital. **No. 1488**

Thorium technology is discussed in series of papers now bound in 397-page volume and offered for sale. Topics include melting, refining, structure, properties, fabrication, corrosion, production of compounds. **No. 1489**

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Alcohols: Ethyl (pure and all specially denatured formulas); Anhydrous and Regular Proprietary Denatured Alcohol Solvents: SOLOX®, FILMEX®, ANSOL® M, ANSOL PR.

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Pharmaceutical Products: DL-Methionine, N-Acetyl-DL-Methionine, Urethan USP, Riboflavin USP, Intermediates.

Heavy Chemicals: Anhydrous Ammonia, Ammonium Nitrate, Nitric Acid, Nitrogen Fertilizer Solutions, Phosphatic Fertilizer Solution, Sulfuric Acid, Caustic Soda, Chlorine, Metallic Sodium, Sodium Peroxide, Sodium Sulfite, Sodium Sulfate.

PETROTHENE® Polyethylene Resins

Animal Feed Products: Antibiotic Feed Supplements, BHT Products (Antioxidant), Calcium Pantothenate, Choline Chloride, CURBAY B-G®, Special Liquid CURBAY, VACATONE®, Menadione (Vitamin K_3), DL-Methionine, MOREA® Premix, Niacin USP, Riboflavin Products, Special Mixes, U.S.I. Permadry, Vitamin B_{12} Feed Supplements, Vitamin D_3, Vitamin E Products, Vitamin E and BHT Products.

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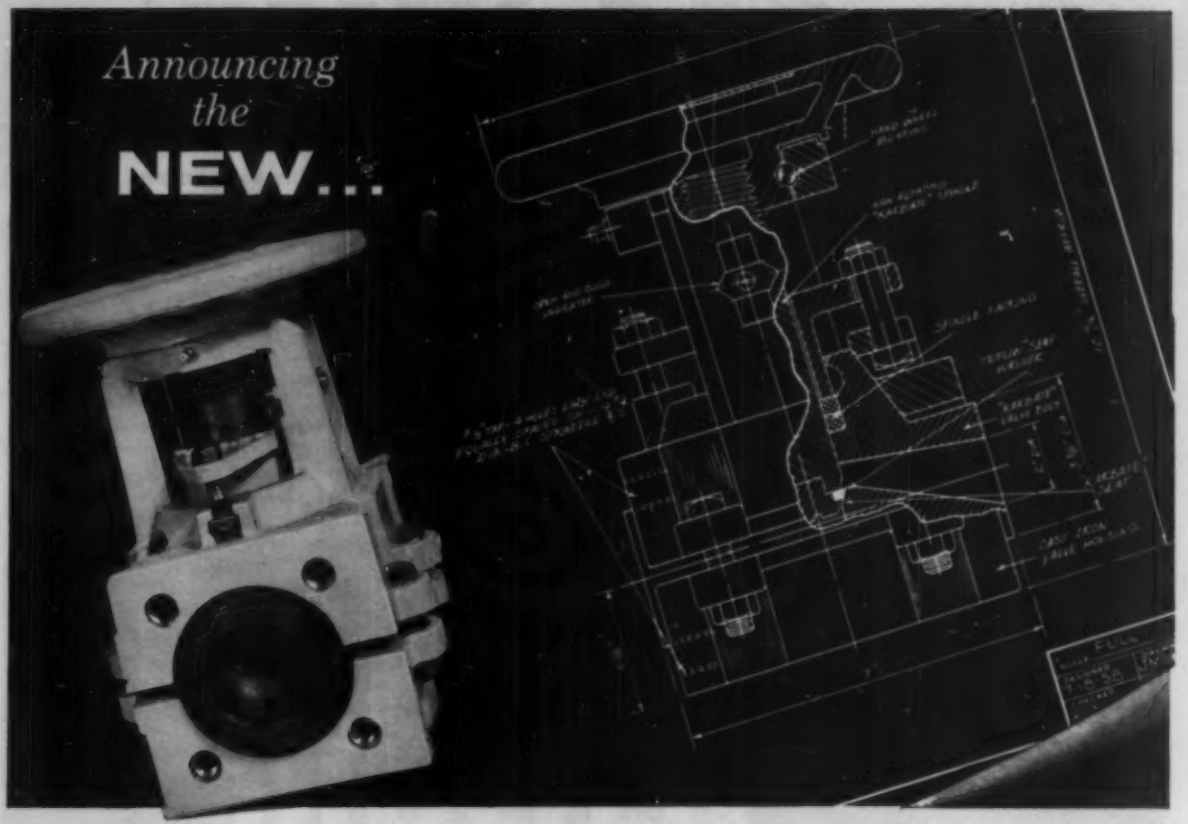

"KARBATE" GLOBE VALVE TYPE G

National Carbon Company announces the availability of a completely new "Karbate" impervious graphite globe valve. The many new design features of this valve were performance tested for approximately 1 year prior to adoption.

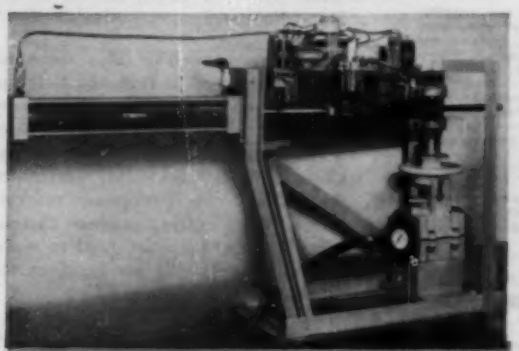

Photo shows test equipment for opening and closing valve to simulate years of actual plant operation. This set-up provided checks on the wearing qualities of spindle threads, sealing qualities of the "Teflon" plastic to carbon seat, and the leak-proof operation of spindle packings.

Principal design features:

- **"Teflon" plastic to carbon seat**—provides positive seal when valve is closed.
- **Metal handwheel to "Karbate" spindle thread design** — provides long operational life — no binding because of corrosion.
- **Non-rotating spindle**—simplifies spindle packing problem. Provides leak-tight seal using a variety of packings such as asbestos impregnated with "Teflon" plastic, braided "Teflon" plastic, asbestos impregnated with graphite and elastomers.
- **Lubricated ball-bearing handwheel to yoke arrangement**—provides easy movement of handwheel with positive lock to yoke.
- **Armored design**—prevents outside shock damage.
- **Positive indication of open and closed positions.**
- **Valve can be adapted to motor operation.**
- **Almost universal corrosion resistance**—can be used in a wide variety of corrosive chemicals. All wetted parts are "Karbate" impervious graphite or "Teflon" plastic.

Presently, this valve is available in the two inch size. One inch, one and one-half inch, three inch and four inch valves will be added to the line in the future.

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Tar distillation

from page 84

tom of a multi-plate fractionation tower. The overhead from this tower is in the solvent naphtha range, and contains the tar acids and the cumerone-indene resins. Two side draws are taken; one of highly concentrated naphthalene: the second, oils boiling in the creosote range. Heat is recovered from the creosote fraction by exchange with the feed tar.

The column operates at a high vacuum provided by a two-stage steam ejector. The melting point of the pitch residue in the bottom of the column is controlled by the temperature of the feed tar and the creosote draw-off.

Equipment is of mild steel and 316 stainless. Caustic soda is metered into the feed tar stream to neutralize small amounts of ammonium chloride which decompose in the upper half of the column. For higher melting point pitches, the residue from this still is passed through a second heater, and the pitch topped off to the required melting point.

In design of the plant, which was by Canadian Badger, pollution control was a primary consideration. Major problem was oil and phenolics. A separate drain system picks up all waste process water which passes first through a A.P.I. type separator which knocks the oil down to 10 ppm. It then goes to a biological treatment tank for removal of phenolics. Effluent from this tank contains no more than one part per million of phenolics compared with a concentration of 1,500 ppm in the feed. The dephenolized effluent is further diluted with clean waste water to the required limit of 20 parts per billion. Air pollution is controlled by oil seals on all product tanks containing hot pitch.

A polyethylene plant, and vinylidene chloride and chlorothene production facilities are included in a $12 million expansion program planned at Dow Chemicals' Louisiana Division. Work starts immediately at Plaquemime on the Mississippi River, with the polyethylene works scheduled to go on-stream in 18 months. Target for the other units is mid-1961.

Fuel reprocessing plant for Oak Ridge

New facility will combine existing chemical reprocessing pilot plants with new "head-end" cells to permit treatment of wide variety of fuel elements.

Present facilities at Oak Ridge National Laboratory, including a Thorex pilot plant, a waste metal recovery pilot plant, and a fission products pilot plant, will be interconnected to allow reprocessing of irradiated reactor fuels containing various combinations of uranium, thorium and plutonium metals, oxides, and alloys. Consultation, design, and construction supervision for the new unit have been entrusted to Vitro Engineering. Process design and chemical criteria for the system are being developed by the Oak Ridge Laboratory staff.

It is claimed that the new facilities will permit reprocessing of fuel elements larger than any previously handled, including those clad with extremely corrosive-resistant metals and alloys such as stainless steel and zirconium.

An oil carbon black manufacturing plant in the Union of South Africa will be constructed by Phillips Carbon Black Co. Ltd. With an initial design capacity of 22,000,000 pounds per year of oil blacks, the unit is scheduled to be in operation within two years. Location of the newly formed company, equally owned by Phillips Petroleum and Industrial Development Corp. of South Africa, is now being finalized.

A European nuclear sales office has been established in Brussels, Belgium, by Babcock and Wilcox Company. The new office will maintain liaison with the European Atomic Energy Community (EURATOM), and represent B&W in European markets. Ralph W. Deuster, nuclear systems specialist, has been assigned to represent the firm, with his headquarters in Brussels.

Construction of a $3 million liquid oxygen, nitrogen, and argon plant has begun in Richmond, California. The new Air Reduction Pacific Co. plant will produce 30 tons daily, and will serve the missiles, metal-working and steel industries in the San Francisco area. Completion of the facility is expected by the end of the year.

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EIMCO *design and production*
PROGRESS REPORT
B - 305

Process Engineers, Inc., division of The Eimco Corporation: 420 Peninsular Ave., San Mateo, Calif.

World's Largest Covered Thickeners in Operation At U. S. Borax & Chemical

Four 230 ft. dia. Eimco-Process heavy-duty thickeners have been in operation for over a year at the United States Borax and Chemical Corporation refinery in Boron, California. These totally enclosed and insulated thickeners, largest of their kind in the world, are part of the CCD circuit from which the strong Borax solution goes to crystallization.

The thickener designs, developed in close cooperation with Pacific Coast Borax Division personnel and the engineering constructors, are custom-adaptations of Eimco-Process Type CX mechanisms. The cover of each unit is supported from radial trusses receiving central support from an 8 ft. dia. concrete column with steel shell that also carries the entire weight and torque of the thickener mechanism. The drive-head with split main gear and bearing was designed to the specific requirement of providing easy maintenance access. A special liquid seal was devised to protect the drive unit from tank vapors, as well as to ensure close control of process conditions.

Four totally enclosed Eimco-Process thickeners at Boron, California

Other installation features were the resting of the steel thickener tanks on oiled sand for corrosion prevention; continuous torque recording; and handling the thickener underflows with steam driven reciprocating pumps.

This $20,000,000 processing plant, on an 80 acre desert site, was designed and constructed by Southwestern Engineering Company and Ford J. Twaits Company as a joint venture. It has substantially increased the U. S. Borax capacity and is playing an important part in the production of high energy boron fuels for the space age.

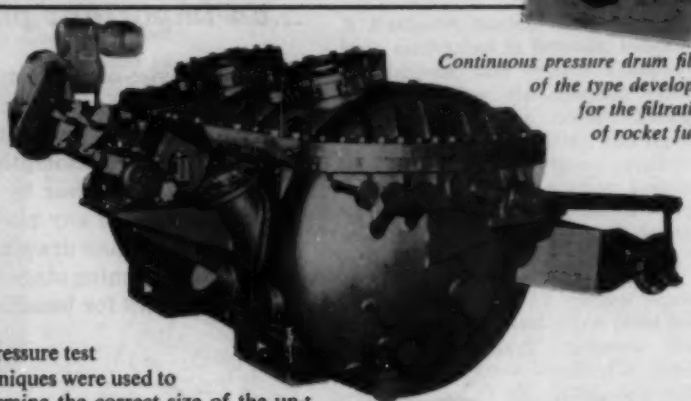
NEW BULLETIN AVAILABLE

We recently completed an eight page bulletin describing our thickeners, hydroseparators, air-lift agitators, reactor-thickeners, slurry mixers and related equipment. It also covers recent design innovations such as our unique Thixo arms and platform lifting devices, and should be in your reference library even if your immediate plans do not include thickening equipment. A request will bring one by return mail, or, if your plans *do* involve thickeners, our nearest sales engineer will deliver a copy in person.

Eimco Filtration Equipment Plays Important Role in Producing Rocket Fuels

At another plant, producing high energy fuels, engineers were faced with a troublesome filtration problem. They had to filter a fuel having an extremely low slurry viscosity, a high percentage of hydrogen in the gas, and containing a dangerously flammable material.

This problem was referred to Eimco's Research and Development center at Palatine, Illinois. Here, the Company's filtration research engineers, after a series of tests, were able to work out special adaptations for a continuous pressure drum filter that met all the specialized application requirements.



Continuous pressure drum filter of the type developed for the filtration of rocket fuels

Pressure test techniques were used to determine the correct size of the unit. Intricate seals were devised to keep air out of the pressure vessel. Changes were made in the hydraulic system. And, the filter was furnished with complete instrumentation.

This is typical of how Eimco's unexcelled research facilities and valuable backlog of experience in engineering custom-designed filter equipment can solve difficult filtration problems.

For more information, turn to Data Service card, circle No. 73

Advertisement

A.I.Ch.E. JOURNAL

HEMICAL ENGINEERING RESEARCH AND DEVELOPMENT / **JUNE 1959**

CONTENTS

The Sea and the A. E. C.	
Mass Transfer at Low Flow Rates in a Packed Column	V. P. Dorweiler and R. W. Fahien
Axial Mixing and Extraction Efficiency	C. A. Sleicher, Jr.
Effect of a Volume Heat Source on Free Convection Heat Transfer	I. E. Randall and Alexander Sesonske
Reduced Density Correlation for Hydrogen: Liquid and Gaseous States	Charles A. Schaefer and George Thodos
An Improved Equation of State for Gases	Joseph J. Martin, Rajendra M. Kapoor, and Noel De Nevers
Solubility of Liquids in Compressed Hydrogen, Nitrogen, and Carbon Dioxide	J. M. Prausnitz and P. R. Benson
Interfacial Resistance in the Absorption of Oxygen by Water	S. H. Chiang and H. L. Toor
Factors Affecting Density Transients in a Fluidized Bed	James M. Dotson
Viscous Flow Relative to Arrays of Cylinders	John Happel
Mass Transfer from a Solid Sphere to Water in Highly Turbulent Flow	L. R. Steele and C. J. Geankoplis
Turbulent Flow of Pseudoplastic Polymer Solutions in Straight Cylindrical Tubes	Robert G. Shaver and Edward W. Merrill
Turbulent Flow of Non-Newtonian Systems	D. W. Dodge and A. B. Metzner
Characteristics of Transition Flow Between Parallel Plates	G. A. Whan and R. R. Rothfus
Treatment of Thermodynamic Data for Homogeneous Binary Systems	H. C. Van Ness and R. V. Mrazek
The Molecular Structure of Liquids	John S. Dahler
Chromatographic Columns Containing a Large Number of Theoretical Plates	A. S. Said
Two-dimensional Laminar-flow Analysis, Utilizing a Doubly Refracting Liquid	John W. Prados and F. N. Peebles
Liquid-Side Mass Transfer Coefficients in Packed Towers	Kakusaburo Onda, Eizo Sada and Yasuhiro Murase
The Dynamics of Heat Removal from a Continuous Agitated-tank Reactor	R. J. Fanning and C. M. Sliepcevich
Turbulent Liquid Flow Down Vertical Walls	H. H. Belkin, A. A. MacLeod, C. C. Monrad and R. R. Rothfus
Phase Equilibria in Mixtures of Polar and Nonpolar Compounds: Derived Thermodynamic Quantities for Alcohols and Hydrocarbons	Cline Black
Heat Transfer and Fluid Dynamics in Mercury-Water Spray Columns	R. D. Pierce, O. E. Dwyer, and J. J. Martin
Flow Characteristics in Horizontal Fluidized Solids Transport	Chin-Yung Wen and H. P. Simons
Effective Diffusivity of Packed Bed	M. Kimura, K. Ueda, and T. Ofuka
Communications to the Editor	
Physical Interpretation of the Relaxation Method in Heat Conduction Heat Transfer	John S. Thomsen
Diffusion in a Pore of Irregular Cross Section—a Simplified Treatment	Leonard Wender and G. T. Cooper
Slot Capacity of Bubble Caps	Alan S. Michaels
Books	Andrew Pusheng Ting

TURN

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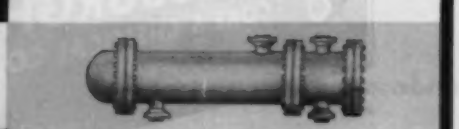

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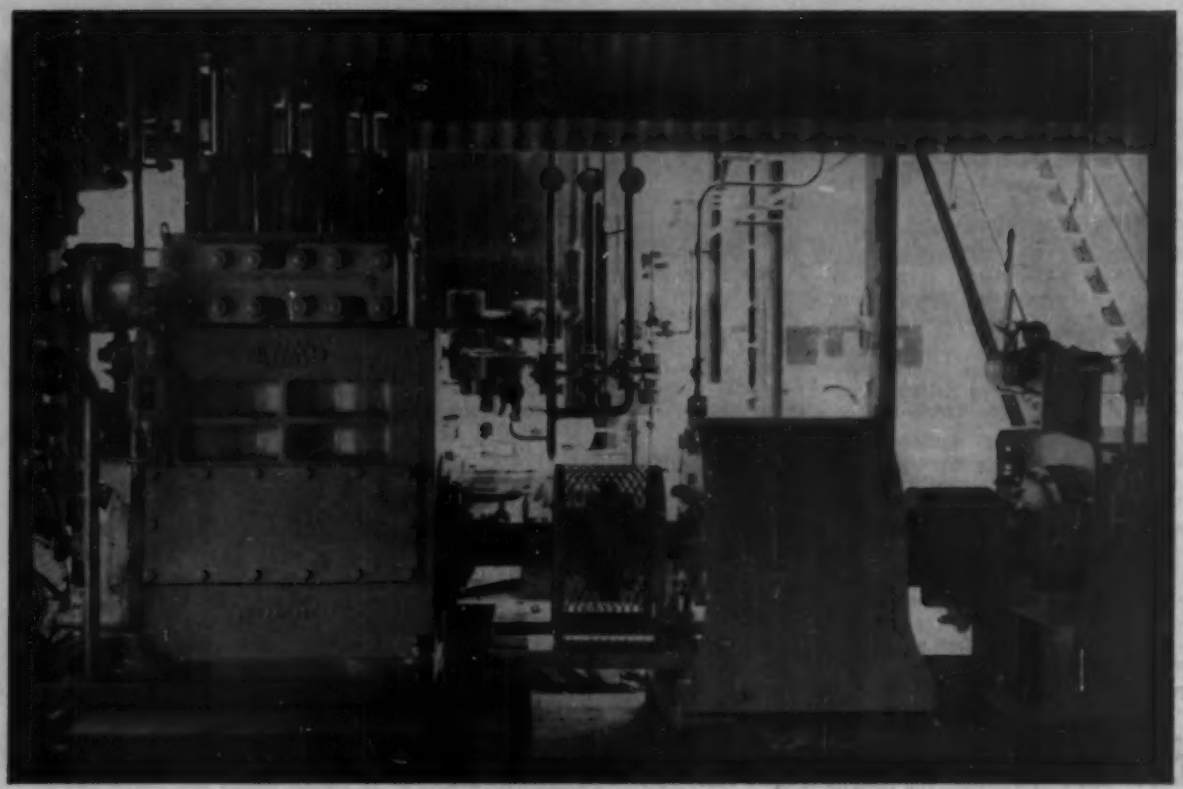

THE PRESSURES ARE HIGH...THE LIQUIDS CORROSIVE...THE PUMPS ARE ALDRICH...

At the Houston plant of Rohm & Haas Co., this Aldrich pump alternately introduces caustic and brine into one phase of the acrylate process for producing acrylic monomers.

The problem: Handle highly corrosive liquids at 3000 psi in a continuous process and *not* have severe maintenance problems.

What Rohm & Haas did about it. Company engineers specified Aldrich 1⅝" x 5" stroke Triplex Pumps for three reasons.

1. Compact, heavy-duty construction makes Aldrich pumps ideal for high pressure service.

2. Aldrich pumps are designed for easy maintenance. Fluid-end sectionalization permits quick removal of valves for inspection or replacement. No special tools are required.

3. Aldrich engineers can draw upon a vast store of experience when it comes to selecting the right materials for any pumping job. In this case, the entire fluid end . . . working barrel, suction and discharge manifolds . . . are forged Monel. Valve seats are Haynes Stellite. Valves and plungers are K Monel.

Results: According to the Plant Manager of the Houston plant, "maintenance requirements have decreased and pumping production improved. These Aldrich pumps lend themselves to easy maintenance."

How Aldrich can help you. Solving pumping problems like this requires specialized engineering skills and experience. We have those skills, and our experience comes from years of working with the chemical industry. We welcome the opportunity to discuss your specific problems . . . no matter what the liquid or how high the pressures. Aldrich Pump Company, 20 Gordon Street, Allentown, Pa.

the toughest pumping problems go to ALDRICH

For more information, turn to Data Service card, circle No. 56

CEP'S DATA SERVICE—Subject guide to advertised products and services

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 97

Equipment

continued from page 98

Mixers, top or bottom entering (p. OBC). Turbine, paddle, and propeller types, 1 to 500 hp. Bulletin 102 from Mixing Equipment. **Circle 17-1.**

Mixers, turbine-type (p. 81). General Turbo-Mixer Bulletin from Turbo-Mixer Div., General American Transportation. **Circle 72.**

Nozzles, spray (p. 156). Catalog 5600 from Binks Mfg. gives applications, sizes, capacities, spray patterns, materials of construction. **Circle 19.**

Packings, tower (p. 36). Bulletin TP-54 from U. S. Stoneware gives full info on Pall rings, other tower packings. **Circle 106.**

Packing, tower (p. 156). Bulletins and technical data from Packed Column Corp. **Circle 101.**

Preheaters, air (p. 147). Reprint of case history of savings by use of a Ljungstrom air preheater offered by Air Preheater Corp. **Circle 21.**

Pumps, canned (p. 123). Pump and motor in single, leakproof unit. Data Sheet from Chempump. **Circle 8.**

Pumps, centrifugal (p. 34). 316 stainless or cast iron, conventional packing or mechanical seal. Info from Dean Brothers Pumps. **Circle 62.**

Pumps, centrifugal (p. 109). Bulletins 721.6 and 722.6 from Goulds Pumps describe single- and double-stage centrifugal pumps which feature interchangeability of parts. **Circle 63.**

Pumps, corrosion-resistant (p. 25). Data from Eco Engineering on rotary gear and centrifugal pumps. **Circle 35.**

Pumps, process (p. 99). Consulting services available from Aldrich Pump on all types. **Circle 56.**

Pumps, rotary gear (p. 146). New Bulletin G-1 from Schutte and Koerting gives full details on standard models. **Circle 75.**

Pumps screw (p. 130). Technical Bulletin 206 from Warren Pumps on external gear and bearing screw pumps. **Circle 99.**

Pumps, top-suction (p. 114). Specially designed to handle volatile sludges and slurries. Data from Lawrence Pumps. **Circle 67.**

Recorder-Controllers (p. 144-145). Bulletin 13-18 from Foxboro gives complete details of pneumatic "Consotrol" recorder-controllers. **Circle 46.**

Screeners (p. 154). Screen powders, liquids, and slurries in 4 to 400 meshes. Details from J. M. Lehmann on its "Vorti-Siv" screener. **Circle 55.**

Scrubbers, fume, jet-Venturi (p. 10). Complete Catalog from Croll-Reynolds. **Circle 103.**

Separators, entrainment (p. 4). Bulletin 21 from Otto H. York describes application of Yorkmesh Demisters to improve performance of process vessels. **Circle 105.**

Shaft Seals, mechanical (p. 138). Provide positive, leakproof seal around any rotating shaft. Technical details from Syntron. **Circle 90.**

Sifters (p. 5). Single or multiple separations down to 325 mesh. Bulletin 503 from B. F. Gump describes the "Bar-Nun" sifter. **Circle 20.**

Thickeners (p. 90). New Bulletin from Eimco describes thickeners, hydro-separators, air-lift agitators, reactor-thickeners, slurry mixers, related equipment. **Circle 73.**

Valves, gate, all-jacketed (p. 136). Specially designed for hard-to-handle viscous materials. Data from Hetherington & Berner. **Circle 12.**

Valves, globe, impervious graphite (p. 87). All wetted parts of Karbate impervious graphite or Teflon. Technical data from National Carbon. **Circle 104.**

Valves, porcelain (p. 9). Lapp Insulator offers description and specifications of porcelain valves bonded to multiple layers of fiberglass. **Circle 31.**

Vapor Condenser (p. 151). Unit capacities up to 15 million Btu. Bulletin 129R from Niagara Blower on the "Aero" (air-cooled) vapor condenser. **Circle 15.**

Vessels, storage and pressure (p. 119). In all special metals and alloys. Technical data from Ellicott Fabricators. **Circle 102.**

Water Analyzer (p. 136). Compact testing set makes fast, accurate tests for color, ammonia, nitrite, nitrate, chlorine, etc. Details from W. A. Taylor. **Circle 13-2.**

CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 95

EQUIPMENT

301 Agitators, propeller-type. Data from Denver Equipment on agitators with propellers up to 96 in. diameter for heavy slurry duty.

302 Agitators, steam-jet. Technical bulletins from Heil Process Equipment describe use of specially-designed steam-jet agitators for heavy-duty sparging of corrosive chemical solutions.

303 Centrifuges. New 16-page Bulletin 2606 from Dorr-Oliver describes design, operation, features of "Merco" centrifugal separators for 5 basic liquids-solids applications.

304 Conveyors, belt. New 88-page Engineering Data Book ID-591 gives complete data on all types of belt conveyors and accessories. Continental Gin Co.

305 Coolers, liquid, packaged. Furnished as complete unit with storage tank, for pilot plant work. Data Sheet from Doyle & Roth.

continued on page 102

MATERIALS

346 Alloys, molybdenum-containing. New 10-page Booklet from Cooper Alloy gives composition ranges, corrosion-resisting properties, high-temperature mechanical properties of molybdenum-containing 18-8 type PH55 (wrought and cast) stainless alloys.

347 Alloy, nickel-base. Specially developed as container material for molten fluoride salts. Brochure from Haynes Stellite Div., Union Carbide, gives development data on Hastelloy alloy N.

348 Amino-Silane. Data Sheet from Dow Corning describes Z-6020, new amino-silane chemical that reacts with both organic and inorganic materials, unites them in strong, durable bond.

349 Attapulgus Clay Products. Technical Information Bulletin 1002 from Minerals & Chemicals lists free moisture content, ignition loss, bulking value, pH, color, specific gravity, residue, bulk density, surface area.

continued on page 102

SERVICES

366 Design and Construction, sulfur recovery plants. New Booklet from Girdler Construction Div., Chemetron Corp., describes economical recovery of sulfur from hydrogen sulfide, air pollution control. Process data, yields, utility requirements, flow sheet.

367 Fabrication, processing equipment. Bulletin YC858 from Yuba Consolidated Industries describes heat exchangers, towers, pressure vessels, structures, tanks.

368 Fabrication, processing equipment. Data from Ellicott Fabricators on storage tanks, hot water generators, heat transfer equipment, "Novelon" linings, special fabrication. Catalog 100-A.

369 Pilot Plant Facilities, waste treatment. Bulletin from Roy F. Weston Inc. describes laboratory and pilot plant facilities, consulting services on water and air pollution control, sewage treatment systems.

continued on page 102

KELLOGG CHECKS OUT

ANOTHER POLYETHYLENE PLANT FOR U.S.I.

Kellogg engineers make a final instrumentation checkout in the utility main control station at U.S.I.'s new Houston plant. If you are interested in the instrumentation phases of Kellogg's complete engineering, procurement, and construction services, send for 12-page Kelloggram, *"The Application of Innovation in Engineering Systems"*.

New 75-million-pound plant is fourth of five Kellogg polyethylene projects for U.S.I.

With the completion by Kellogg of the 75-million-pound plastics plant near Houston, Texas, U. S. Industrial Chemicals Company's total capacity for PETROTHENE® polyethylene will be seven times what it was when U.S.I.'s first facilities went on stream in 1955. Kellogg is privileged to have played a continuing role in this rapid expansion.

Kellogg engineered and built U.S.I.'s first polyethylene manufacturing facilities at Tuscola, Illinois, as well as its Tuscola ammonia plant—added in 1955. In 1956, Kellogg was given the responsibility of doubling Tuscola's polyethylene capacity, and of doubling it again in 1957.

Recently Kellogg completed a polyethylene compounding plant for U.S.I. at its Tuscola complex. Currently Kellogg is working with U.S.I. on plans *now* to double the output of the new polyethylene plant in Houston.

The early and successful completion of Houston at its present 75-million-pound capacity reaffirms U.S.I.'s confidence in Kellogg plant engineering and construction, and is another example of this contracting organization's ability to work harmoniously with engineers of leading chemical companies.

If *you* are contemplating new facilities for the production of plastics, petrochemicals, or other chemical materials, The M. W. Kellogg Company welcomes the opportunity to discuss its world-wide engineering, procurement, and construction experience with you in detail.

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CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 95

Equipment *from page 100*

306 Corrosion Resistant Equipment. New 64-page Bulletin F-7 from Haveg gives technical details, specifications of all types of corrosion-resistant equipment for the chemical processing industry.

307 Cryogenic Refrigerators. New 6-page Folder from Linde (Union Carbide) gives design features, performance data on 4 types of special cryogenic refrigerators.

308 Dall Flow Tubes, plastic. Technical data from B-I-F Industries on plastic Dall flow tubes for line sizes up to 48 in.

DEVELOPMENT OF THE MONTH

NEW LEAKPROOF VALVE

(Circle 602 on Data Post Card)

A compact, leakproof valve, which has no moving parts between the fluid chamber and the atmosphere, and which can safely handle radioactive and toxic fluids, has been designed and patented by Singmaster & Breyer.

Suitable for either tight shut-off or automatic throttling of gases or liquids, the valve has negligible pressure drop across the closure disc. The internals can be made of any weldable corrosion-resistant material, while externals can be of conventional brass or steel. Limits of design working temperatures are minus 20 to plus 1,500°F; design working pressures range from 0.005 microns vacuum to 150 lb./sq.in. in smaller sizes, and to 30 lb./sq.in. up to 72 in diameter.

Heart of the valve is a standard commercial bellows which forms the fluid chamber. The chamber contains only a seat and a disc. There is no opening to the atmosphere, no stuffing box or valve stem. The streamlined disc is opened and closed by pneumatic drive or mechanical gear in 2 to 6 in. sizes, and by mechanical gear drive in 6 to 12 in. sizes. Larger valves, which require hydraulic drive or synchronized motors, must be engineered for specific applications.

For further details on this new valve, Circle 602 on Data Post Card.

309 Dryers, dessicant. Specially designed for air and gas processing at pressures from 1,000 to 6,000 lb./sq. in. Bulletin D-108 from C. M. Kemp Mfg.

310 Fans, duct. Bulletin A-114A from Hartzell Propeller Fan Co. gives technical details of belt-drive, direct-drive, "Bi-pass", and reversible duct fans.

311 Feeders, gravimetric. For accurate, dependable, continuous flow feeding of bulk materials. Bulletin from Syntron.

312 Feeders, rotary airlock. Bulletin P-58 from Prater Pulverizer gives complete engineering specifications, construction details, dimensional drawings.

314 Filter Press, tilting. Filter cake will not fall away from plates during operation even with pressure drop to zero. Data from Terriss Div., Consolidated Siphon Supply.

315 Fittings, stainless, light-wall. New 6-page Bulletin from Chemetron, Tube Turns Div., gives details of stainless fittings and flanges for non-critical process piping.

316 Flowmeters, turbine-type. Design details, complete specifications on new line of Type 20 turbine flowmeters. Technical Bulletin from George L. Nankervis, Cox Instruments Div.

317 Gauges, liquid level. Detailed technical info on construction, design features, specifications of new non-frosting gauge for low temperature work. Jerguson Gage & Valve.

continued on page 104

Materials *from page 98*

350 Coatings, protective. Four-page Chart, "Comparison of Maintenance Coating Systems," compares 17 standard systems. Carboline Co.

351 Coatings, protective. New Folder from Chromalloy Corp. describes 15 commercial applications of a process for diffusing chromium and other elements into the surface of metal parts to increase heat, wear, and corrosion resistance.

352 Dicyclopentadienyliron. Data Sheet from Matheson Coleman & Bell, Div., of Matheson Co., describes characteristics and specifications of "Ferrocene."

353 Emulsifiers. General Mills Research Laboratories announces availability of new series of amino acids fatty acid salts. Technical data and samples.

354 Epoxides. Two Bulletins from Chemicals & Plastics Div., Food Machinery and Chemical. Bulletin 95 on dicylopentadiene dioxide, and Bulletin 96 on limonene dioxide.

355 Ethoxylated Chemicals. Physical properties, emulsification characteristics, industrial applications contained in Booklet from Armour Chemical Division.

356 Filter Paper. Bulletin 12 from National Filter Media Corp. gives mechanical, chemical properties of "Netone" filter papers.

357 Fluorinated Compounds. Chemical, physical, and electrical properties, toxicity, and solubility of line of fluorinated waxes, oils, and greases contained in 12-page Brochure from Halocarbon Products.

358 Imidazole Derivatives. New 11-page Technical Bulletin from Houdry Process Corp. gives complete info on various imidazole derivatives.

359 Joint Sealer, Teflon. Info from Crane Packing on new tape-type joint sealer made of Teflon. Temperature range from minus 250 to plus 500°F.

360 Plastics. New 64-page Catalog and Price List gives sizes, weights, color ranges, specifications, grades, and prices of sheets, rods, tubes, films, blocks, flat tubing. Cadillac Plastic & Chemical.

361 Plasticizers. New Booklet from Monsanto Chemical gives properties and specifications of 7 plasticizers recommended for nontoxic applications.

362 Polyethylene Copolymer. Data from Union Carbide Plastics describes properties, applications of new injection molding compound.

363 Silanes. New 16-page Booklet from Union Carbide, Silicones Div., gives physical and chemical properties, product specifications, shipping data.

364 Surfactants, nonionic. Technical Bulletin from Antara Chemicals, General Aniline & Film, gives properties of "Emulphogene BC," family of nonionic surfactants.

365 Uranium & Thorium Foil. Data Sheet from M & C Nuclear describes fabricating procedures, gives typical specifications, maximum and minimum dimensions.

Services *from page 100*

370 Tables and Formulas. New Booklet from Westinghouse Electric has 120 pages of convenient tables, formulas, graphical symbols on electrical data, heat transfer and steam information, measurements.

371 Testing Services, chemical. New Bulletin 5901 from United States Testing describes complete line of chemical laboratory testing and research facilities.

372 Viscosity Determination. Data Sheet from Brookfield Engineering Laboratories lists 26 technical papers, plus several books on viscosity.

News from
National Carbon Company
Division of Union Carbide Corporation • 30 East 42nd Street, New York 17, N. Y.
Sales Offices: Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco. IN CANADA: Union Carbide Canada Limited, Toronto

National Carbon representatives expand your engineering force

T. W. MANCHESTER – SALES ENGINEER

Mr. Manchester was graduated from Pennsylvania State University with a B. S. Degree in Chemical Engineering. For nine years he worked as a Product and Process Control Engineer at National Carbon's Clarksburg and Columbia Plants. Here he was involved with production control for the manufacture of electrodes, anodes and specialty grades of graphite.

After joining the Chemical Products Sales Group, Manchester worked for a period in the design group. Since 1958, he has been a field engineer covering the Southeastern Sales District.

LARGE DIAMETER GRAPHITE STOCK FILLS NEED OF CHEMICAL PROCESS INDUSTRY

Unloading 61" diameter x 72" long graphite from graphitizing furnace

National Carbon Company has completed production of the largest diameter fine-grained graphite specialty stock ever produced. These pieces are 61" in diameter, 72" long and weigh approximately 7 tons each.

The production of this large size graphite allows fabrication of essentially monolithic high temperature process equipment. Monolithic construction lends itself to easier field erection and lower maintenance because it minimizes the number of joints required.

Five of these pieces are to be machined into sections for a graphite tower. The tower will be used for production of phosphoric acid from the burning of elemental phosphorous.

This is another example of National Carbon's continuing research, development and production efforts to meet the growing demands of the chemical processing, nuclear, and aircraft industries for large size graphite stock.

Carbon and Graphite unmatched as materials for high-temperature applications

In recent technical articles covering materials of construction for high-temperature chemical processes, reference is made to graphite as the best available material for applications in neutral or reducing atmospheres. At temperatures up to 4000° F., graphite exhibits excellent structural properties such as: no deformation, relatively high strength, immunity to thermal shock and, most important of all, is its complete chemical inertness.

For twenty years, NATIONAL CARBON Engineers have been engaged in designing graphite equipment for use in high-temperature chemical processes. This work has covered both operational and mechanical features of the equipment. Some of the outstanding results of these efforts are: graphite water-cooled combustion chambers for burning elemental phosphorous, carbon or graphite towers for hydrating phosphorous pentoxide to phosphoric acid, graphite linings for high-temperature chlorination of boron, zirconium and columbium, graphite resistance furnaces for heating corrosive gases such as chlorine up to 2500°F., and graphite high-temperature vacuum reaction furnaces for the reduction of ores to the metals.

NATIONAL CARBON Engineers have gained extensive experience in the development of equipment for these high-temperature chemical applications. This experience can prove helpful in the design of equipment for new applications. If you wish to consult a NATIONAL CARBON Engineer, write **National Carbon Company, P. O. Box 6087, Cleveland 1, Ohio.**

NATIONAL
TRADE MARK

"National", "Karbate", "N" and Shield Device and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

UNION CARBIDE

For more information, turn to Data Service card, circle No. 79

CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 95

Equipment *from page 102*

318 Heat Exchangers, graphite, immersion-type. Bulletin from Falls Industries gives construction details, physical properties, and chemical resistance of impervious graphite heat exchangers.

319 Heaters, liquid. Operate at atmospheric pressure to give processing heat up to 650°F. Catalog 162 from Allis-Chalmers.

320 Indicator, bin level. New all-metal "Auto-Bin-Dicator", with stainless diaphragm, is suitable for high and low density, coarse and fine materials. Highly corrosion-resistant. Data from Bin-Dicator Co.

321 Indicator, differential pressure. Barton Instrument offers Data Sheet on new instrument for indication of flow, liquid level, differential pressure.

322 Indicator, solids flow. Data Sheet from Bailey Meter Co. gives construction details, applications of improved solids flow indicator-transmitter.

DEVELOPMENT OF THE MONTH

HIGH-VOLTAGE ELECTRON BEAM PROCESSING

(Circle 603 on Data Post Card)

Technical and economic factors in applying electron-beam radiation to industrial processing, including cross-linking of plastics, polymerization, and initiation of chemical reactions, are covered in a new 32-page Bulletin from High Voltage Engineering.

The new Handbook covers such questions as types and sources of radiation, developing radiation processes from research, engineering factors in design, efficiency of electron-beam utilization, beam power output and production capacity, installation and use of electron-beam accelerators, and the economics of radiation processing.

The bulletin has over 50 illustrations, tables, charts, and graphs, as well as mathematical formulas and worked-out calculations for such variables as optimum weights and thicknesses of processed material, and power requirements per pound and linear rates. Also an extensive bibliography. For a copy of the handbook, Circle 603 on Data Post Card.

323 Mills, attrition. Data Sheet from Munson Mill Machinery gives technical info, specifications of double- and single-disc mills.

324 Mills, hammer, vertical. New "Pulver-Mill," product of Sturtevant Mill, has integral air classifier, is designed for extremely fine grinding of soft, nonmetallic materials. Technical data.

325 Mixers, batch, tilting. Bulletin B-12 from Gruendler Crusher & Pulverizer gives complete specifications and dimensional data.

326 Particle Size Distribution Analysis. Bulletin 101 from Sharples describes the "Micromerograph," new instrument for accurate, rapid, reproducible particle size distribution analysis.

327 Piping. Technical Data Card from Babcock & Wilcox gives dimensions and weights per foot of pipe in sizes from ⅛ through 36 in. for all schedules.

328 Pulverizers, small. Bulletin 51F-1 from Pulverizing Machinery Div., Metals Disintegrating, gives capacities, materals specifications, mesh finenesses, for its "Bantam Mikro-Pulverizer."

329 Pumps, canned, for nuclear service. New Technical Bulletin from Chempump indicates uses and advantages of zero-leakage centrifugal pumps in the nuclear field.

331 Pump, metering, chemical. New Model CM, product of Milton Roy, delivers maximum capacities to 28 gal./hr. against pressures to 1,100 lb./sq. in. Technical details.

332 Pumps, rotary, internal gear. Construction, dimensions, performance data in Bulletin from Wayne Pump.

333 Spectrophotometer Accessories. Data from Perkin-Elmer on two new accessories for its Model 4000-A Ultraviolet-Visible-Near Infrared spectrophotometer: a specular reflectance attachment, and a diffuse reflectance attachment.

334 Submerged Combustion Systems. Bulletin 101 from Submerged Combustion Inc. describes use of flame-to-liquid heating in chemical operations.

335 Thermocouple Wire. Insulated, metal-sheathed wire, designed to withstand ambient temperatures of more than 2,000°F. Twelve standard constructions, gage sizes from 15 to 28. Data from Revere Corp. of America.

336 Transfer Hose, Teflon. Inert to all acids and industrial chemicals. Available now in 1½, 2, and 3 in. diameters. Data from Resistoflex.

337 Tubing, small. Technical Bulletin from Superior Tube gives chemical composition, physical constants, mechanical properties of Inconel, Inconel "X," Inconel "702," Ni-o-nel, Incoloy in tubing form.

338 Valves, butterfly. Bulletin 583 from W. S. Rockwell Co. gives construction details, selection data on butterfly valves with manual or automatic control and shut-off.

339 Valves, plastic-coated. Technical data from DeZurik Corp. on cast iron valves with plastic coatings.

340 Valves, pressure-reducing. Bulletin J-160 from OPW-Jordan gives construction details, pressure ratings, flow curve.

342 Valve Stem Assemblies, packless. Data from Robertshaw-Fulton Controls on new assemblies with seamless bellows made of titanium for nuclear work.

343 Viscometers. Newely-designed indicator-controller can be located at distance from measuring element, can be fitted with high and low density alarms. Data from Norcross.

344 Water Treatment Equipment. Bulletin SM-1013 from Process Engineers (Eimco) features the "Reactor-Clarifier" which combines coagulation, flocculation, sedimentation, sludge removal in single operation.

345 Weighing Systems. Weighing & Control Components Inc. offers Catalog 12 describing measurement and control of bulk materials flow through "unitized" systems.

DEVELOPMENT OF THE MONTH

PORTABLE PLASTIC PUMP

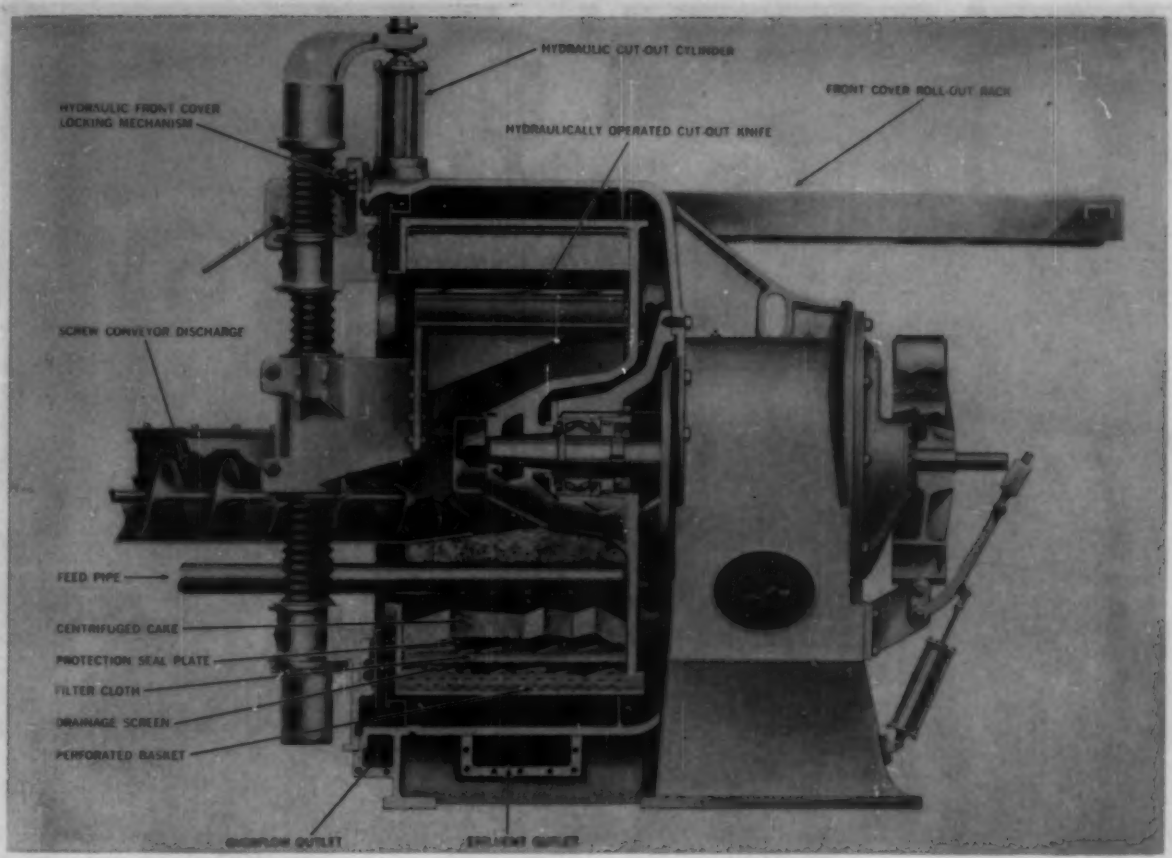
(Circle 601 on Data Post Card)

Innovation by Vanton Pump and Equipment is the "Tote-A-Pump", portable sealless plastic pump designed for handling corrosive and abrasive materials in the field or in locations where it would normally be difficult to arrange a pumping system.

Unit pictured is the Model XB120 with a capacity of 20 gal./min. Pump body blocks and liners are available in a wide variety of corrosion-resistant plastic materials in a capacity range from 1/10 to 40 gal./min. For more info on this handy unit, Circle 601 on Data Post Card.

A.I.Ch.E. Membership

Brochure—"Know Your Institute"—tells objective aim and benefits to chemical engineers who join this nation-wide organization, includes membership blank. Circle number 604 on Data Post Card.



For Top Performance—it's always REINEVELD

H&P CYCLONES

When classifying or thickening slurries is required, the most economical tool for a plant desiring continuous flow is the H & P Cyclone. Heyl & Patterson carries a complete line of various sizes and capacities of Cyclones, including the new 1⅛"-14° Cyclone.

For any given bowl diameter, the Reineveld Centrifugal produces the greatest force field. Its lower product moisture, higher capacity and more economical operation are functions of these higher G's.

The cut-away view clearly illustrates the superior design, high-lighted by the patented centrally located main bearing. Note also that cleaning and maintenance of the Reineveld is reduced to a simple, low-cost operation by quick-opening features such as the roll-out of the hydraulically locked front cover.

Precise workmanship and rugged design make it the outstanding new Centrifugal in its field.

DESIGN DATA OF REINEVELD CENTRIFUGALS

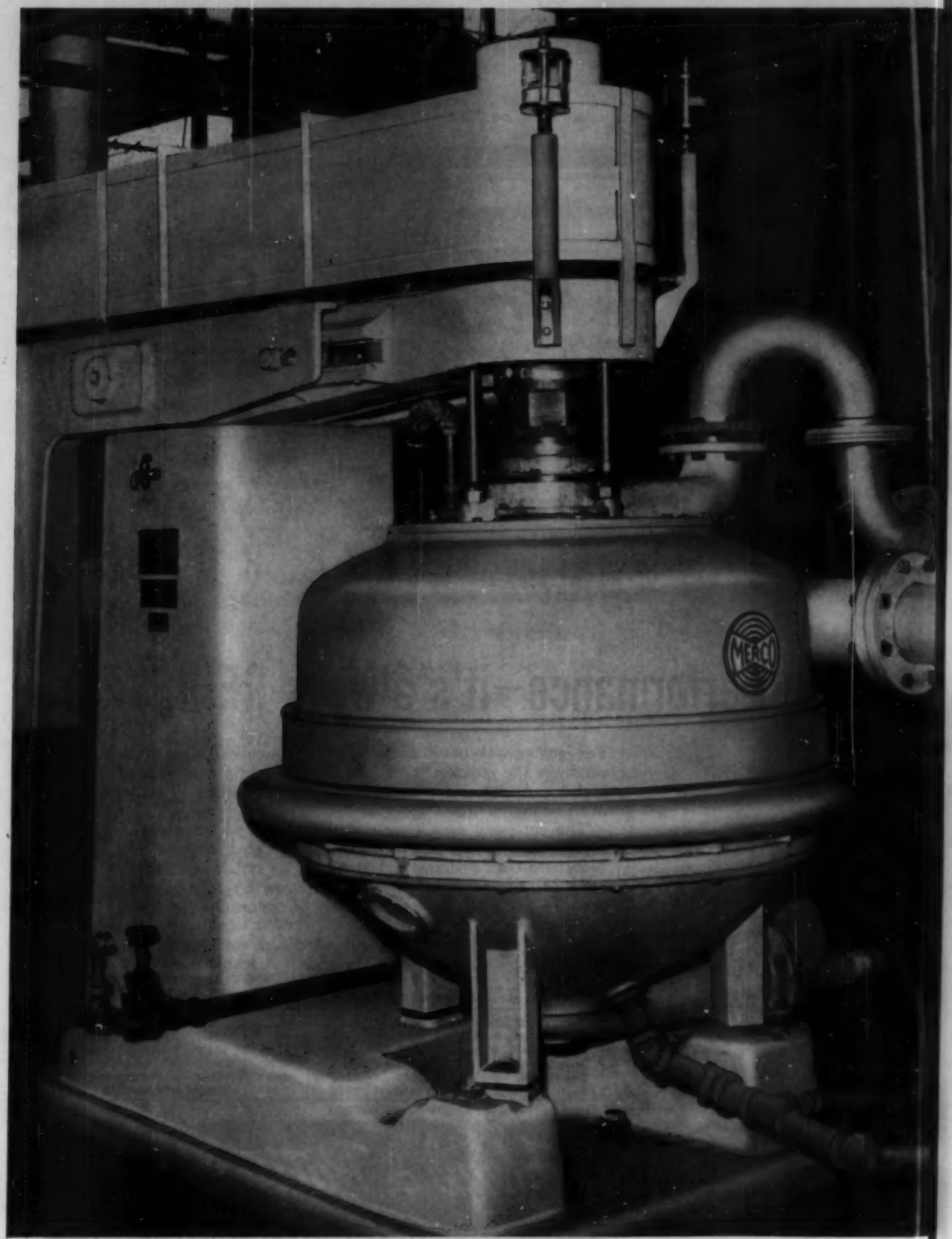
Bowl Diameter	28" S	36"	51"	68"	80"
Bowl Content (cu. ft.)	1.2	4.9	13.2	28.1	43.3
Bowl Content (gallons)	9.0	36.5	99.0	211.0	325.0
Screen Area (sq. ft.)	6.2	13.5	27.4	46.5	65.0
Design RPM	2000	1500	1085	850	750
Equivalent Force (G's)	1560	1140	850	700	625

Consult Heyl & Patterson's listing in CEC or write for Bulletin 356 for Reineveld, or Bulletin 1157 for H & P Cyclones.

Heyl & Patterson INC.

55 FORT PITT BLVD., PITTSBURGH 22, PA., COurt 1-0750

For more information, turn to Data Service card, circle No. 28



New H-30 Merco Centrifuge, with increased speed and capacity, in operation at Argo, Ill. plant of Corn Products Refining Co.

NOW...

increased capacity in NEW MERCO CENTRIFUGE for nozzle bowl applications

Rotor speeds up to 3300 rpm and capacities up to 600 gpm are now possible with the new, improved H-30 Merco Centrifuge. At the same time, power requirements per gallon of feed have been substantially reduced.

In the first two installations, this new unit produced comparable removals at nearly double the capacity of previous models . . . and showed *no increases* in total power consumption.

This new operating efficiency is a result of improvements in rotor design, which provides greater disc area. Feed passages have been enlarged to accommodate increased flow.

The new Merco H-30 Centrifuge is particularly useful for clarification and thickening of slurries which contain fine solids (0.5 micron) over a wide range of feed solids concentrations (.02% and up). It is now available with a 30" stainless steel rotor and bronze or stainless steel housing. In addition to its new large capacity and higher speeds, it contains these standard Merco benefits:

- The unique return flow principle that permits concentrating, washing, clarifying, classifying and recovery of soluble values at pressures up to 150 psi.
- No nozzle clogging or solids build-up in the unit.
- Overhead drive eliminates need for submerged bearing.
- Hydraulic hoist is built in to simplify inspection and maintenance.

If yours is a process that needs a large capacity centrifuge, there is a place for the Merco H-30 in your plant. For further information, write to Dorr-Oliver Incorporated, Stamford, Connecticut.

Merco—Reg. T.M. Pat. Off.

DORR-OLIVER
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WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U.S.A.

For more information, turn to Data Service card, circle No. 57

Cost-Conscious Chromatographs

Increasing use of vapor-phase chromatographs in refining and petrochemical operations seen offering stepped-up efficiency, substantial cost savings.

More and more vapor-phase chromatographs have been installed in recent years in refinery operations, and an increasing number of applications are beginning to be found in petrochemical and chemical plants. These control instruments have been found particularly applicable to such typical processes as alkylation, butane isomerization, light hydrocarbon recovery, butadiene extraction, and ethylene production. The process used here to illustrate the operations is alkylation, taken from data on an actual working installation.*

How it works

In the operation of a typical vapor-phase chromatograph, a metered vapor sample of reproducible volume is introduced into a flowing carrier gas (usually helium), and the mixture is passed into an adsorption or partition analytical column. Different components in the sample will pass through the column at different speeds depending on their physical and chemical properties when in contact with the column packing materials.

A detector at the outlet of the column presents a voltage (usually DC) varying in magnitude as a measure of the concentration of each fraction eluted from the column. The detector is usually a thermal conductivity cell, although several other methods have been employed.

Programming equipment incorporated in the instrument provides for introducing samples periodically, and for switching attenuators across the detector output at the appropriate time to allow direct reading of component concentrations on a potentiometer recorder. Voltage amplitudes are of sufficient magnitude so that, usually, no intermediate amplification is required. The time cycle for each analysis is usually from 5 to 30 minutes depending on the elution times of the material present in the sample. Instruments will repeat analyses automatically on a predetermined time cycle.

Data are generally recorded in the form of a bar graph which is a convenient means of compressing enough information on the visible portion of a strip chart for the presentation of process trends. Sometimes, instruments are programmed to read out concentrations of as many as eight or ten components, but more commonly they record only three or four.

Alkylation

Butane-butylene alkylation units account, up to now, for a larger number of plant chromatograph installations than any other process classification. Efficient operation of the unit requires good control over the olefin-paraffin feed ratio, and of the light end separation after the reactors. Isobutane must be recycled in high purity, yet excessive iC_4 losses in the butane or propane removed can seriously detract from the unit's profits.

Alkylation units are usually classified according to the acid catalyst used—H_2SO_4 or HF. Figure 1, a simplified flow diagram of an alkylation unit, can be assumed typical of either type.

Olefins and isobutane, along with the acid catalyst, are fed to the reactor where they are combined to form a generally saturated mixture of branched paraffins in the gasoline boiling range. Liquid from the reactor is pumped through an acid separator where the catalyst is separated out and recycled to the reactor. Raw alkylate is passed overhead where traces of acid are removed, and is then sent through a series of fractionation columns where various cuts are made. It is in this fractionation train that most of the chromatographic analyzers have so far been installed.

Sample point 1 — Debutanizer overhead

Raw, acid-free alkylate is fed to the debutanizer column where the light gases are cut out. Liquid alkylate product is removed from the debutanizer bottoms, vapors overhead. Analysis at this point is made for isopentane overhead, the cut being made between normal butane and isopentane. Efficient operation of the debutanizer calls for minimizing isopentane in the overhead without cutting into the C_4's to any large degree. It should be noted that usually the analytical data most significant to the control of a distillation column is the concentration of the *minor* component boiling immediately above the major component in the overhead, or below in the bottoms.

Sample points 2 and 3—Depropanizer overhead and bottoms

Propane is removed from the gas fraction for use as fuel or to be further processed for other refinery uses. The debutanizer overhead, therefore, should be high in propane, while the isobutane should be held at a low level. Any isobutane going overhead at the depropanizer represents an important product loss, besides lowering the fuel value of the propane by

continued on page 110

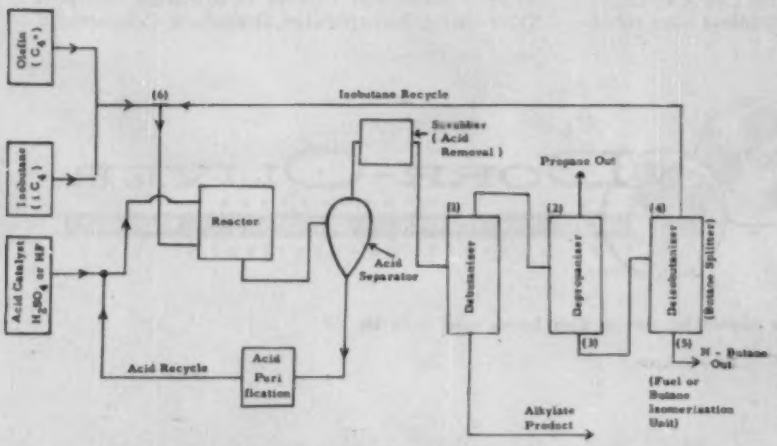
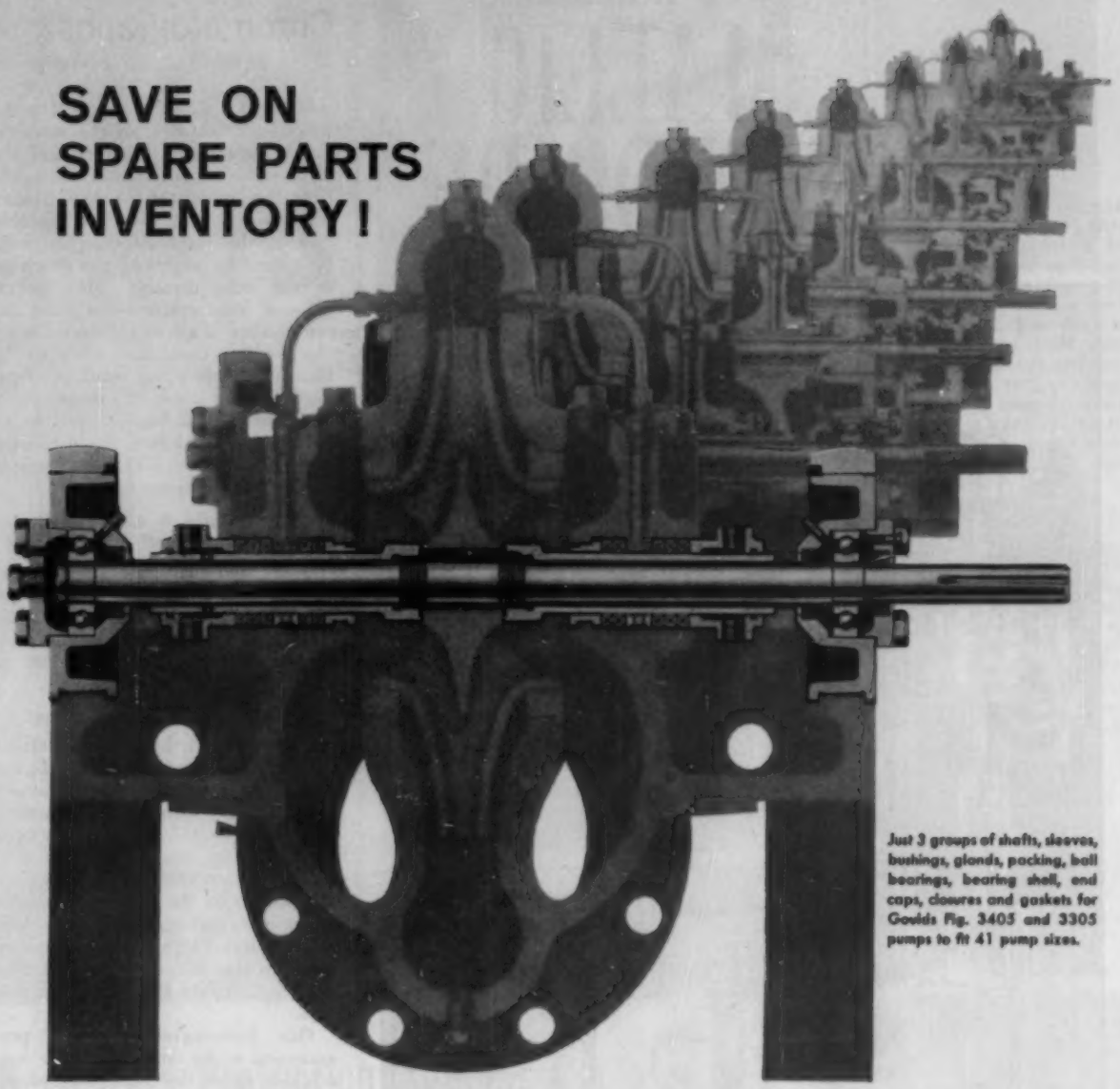


Figure 1. This typical alkylation flow diagram (simplified) is representative of either acid catalyst.

* *The present article is condensed from a more extended treatment by H. McDonnell of the Perkin-Elmer Corp.*

SAVE ON SPARE PARTS INVENTORY!



Just 3 groups of shafts, sleeves, bushings, glands, packing, ball bearings, bearing shell, end caps, closures and gasket for Goulds Fig. 3405 and 3305 pumps to fit 41 pump sizes.

See how just 3 groups of parts fit 41 pump sizes!

High degree of interchangeability of parts on Goulds Fig. 3405 single-stage and Fig. 3305 two-stage Centrifugal Pumps helps you save four ways:

1. You cut down your spare parts inventory.
2. You can make changes in the field to meet new requirements.
3. Off-the-shelf delivery of standardized parts.
4. You can get lower initial cost, due to standardization of parts during manufacture.

Just three shaft and rotating parts assemblies provide for 41 sizes of these two popular pumps. You cut spare parts inventories *up to 91%*, save the cost of unnecessary overstocking.

Up to 82 pump combinations are possible—considering right- and left-hand rotation—and rotation can be changed in the field due to unique sleeve locking device (patented). Mounting dimensions and motor drive bedplates are standardized to facilitate changing without the additional expense of drilling and tapping.

And . . . you get all of this at low cost! Standard parts make manufacture less costly. Goulds passes on the savings to you.

Find out how this maximum interchangeability can save you money by sending for Bulletins 721.6 and 722.6, or ask your nearest Goulds representative.

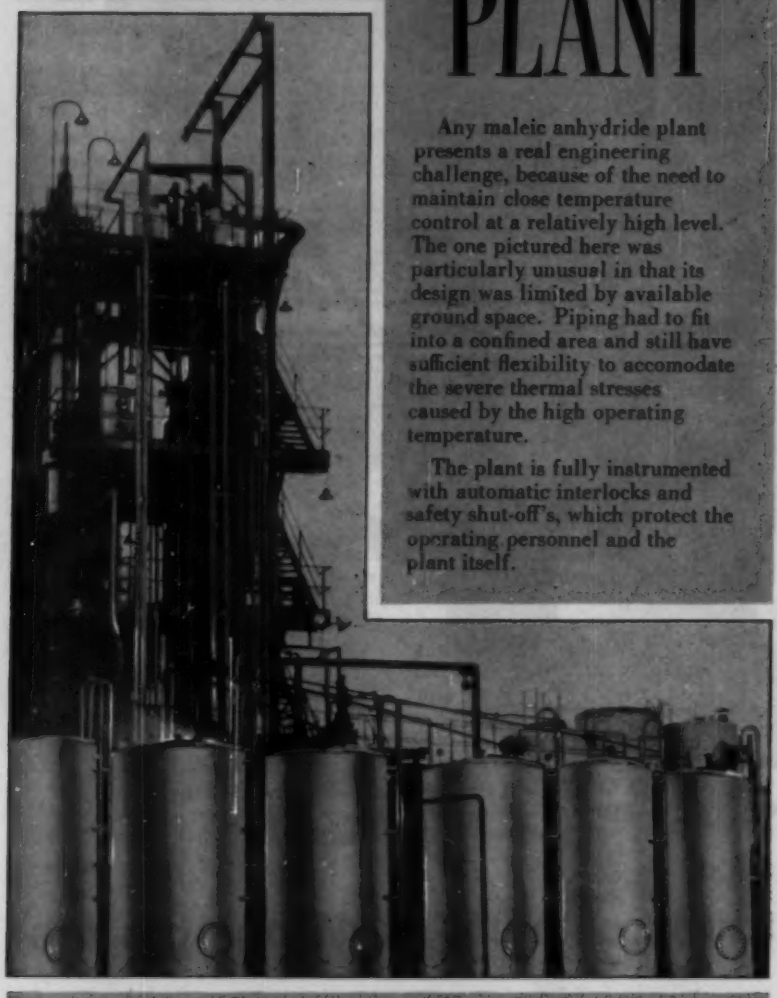
GOULDS PUMPS, INC., Dept. CEP-69, Seneca Falls, N. Y.

GOULDS PUMPS

For more information, turn to Data Service card, circle No. 63

an unusual

MALEIC ANHYDRIDE PLANT



Any maleic anhydride plant presents a real engineering challenge, because of the need to maintain close temperature control at a relatively high level. The one pictured here was particularly unusual in that its design was limited by available ground space. Piping had to fit into a confined area and still have sufficient flexibility to accomodate the severe thermal stresses caused by the high operating temperature.

The plant is fully instrumented with automatic interlocks and safety shut-off's, which protect the operating personnel and the plant itself.

For further details on maleic anhydride plants, or any other chemical plant, contact I★P★E's Process Plants Division, Dept. M.

IPE PRECISION ENGINEERED DEVICES

INDUSTRIAL PROCESS ENGINEERS

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Chromatographs

from page 108

reducing its vapor pressure. The depropanizer bottoms, on the contrary, should be high in isobutane and low in propane. However, since all the C_3 from the bottoms of the depropanizer will go overhead from the deisobutanizer, the same information could be gotten by sampling the overhead of the deisobutanizer. This fact is often of considerable value when the composition of a bottoms stream is too complex for chromatographic analysis. By sampling the overhead from the following tower, the same data is available without difficulty from heavy contaminants. In effect, the distillation column is used as part of the sample preparation equipment.

Sample points 4 and 5—Deisobutanizer overhead and bottoms

These two analyses are believed to be the most frequent in refinery installations to date. This is probably because isobutane is a premium commodity and inefficient operation of this column can be costly.

Sample point 6—Reactor feed

The ratio of isobutane to C_4 olefins in the reactor feed is, of course, an important parameter in operation of the process. Consequently, several users have installed chromatographs to monitor the feed ratio. This analysis, while important, is less common than others in the distillation section of the unit, perhaps because the operator has less control over feed composition to the unit than over changes occuring entirely within his own process.

One instrument could be programmed to do one, several, or conceivably all of the monitoring operations outlined above. But, since each analysis requires about 15 minutes, it is generally undesirable to build up too many sample points on a single analyzer. The time lag can become too great for optimum operation.

Plans for doubling Union Carbide's polyethylene production capacity in the United Kingdom are underway. Facilities at Grangemouth, Scotland, will be increased by the addition of a 30 million pounds a year production unit. Expected to be complete by 1960, the new unit will be operated by Union Carbide Ltd., affiliate of the U.S. firm. This represents the sixth major investment in the European petrochemicals field by the company. Near completion is an ethylene and derivatives plant at Frawley, England.

For more information, turn to Data Service card, circle No. 45

For information, circle No. 48 ➤

Left: Designed to operate under 300 psig. at 450°F, this vessel will be subjected to unusually corrosive service. Hastelloy, a non-ferrous nickel-base alloy, was specified to line the vessel. The ASME Code shell was first lined with narrow strips and segments by manual metallic arc welding. The welds were then covered by cap strips, heliarc welded to the liner. Multiple tests confirmed the excellence of the welds.

Below: Graver's skills in forming and lining vessels to conform to efficient operating requirements is demonstrated by the head for the vessel at the left. Not only must the fit be exact but all welding of the Hastelloy lining must be tight in order to protect the vessel against corrosion and the product against contamination.

Need This Protection Against Corrosion?

Hastelloy is one of the most effective metals to use in vessels requiring maximum protection against corrosion. But at the same time, it calls for precision welding. The cost of Hastelloy usually suggests use as a lining material, which puts a premium on welding skills. Graver has developed an expertness in welding Hastelloy not commonly available elsewhere. The advanced fabricating techniques used are the result of Graver's continuous welding research program. Graver's competence with Hastelloy is one of a number of reasons why it pays to call on Graver for fabrication of all types of alloys.

GRAVER TANK & MFG. CO.
DIVISION—UNION TANK CAR COMPANY
EAST CHICAGO, IND.

GRAVER

Plants and Offices Across America

AEROFIN

TYPE R Removable-Header WATER COILS

- Complete Drainability
- Easily Cleaned
- High Heat Transfer

Completely drainable and easily cleaned, Aerofin Type "R" coils are specially designed for installations where frequent mechanical cleaning of the inside of the tubes is required.

The use of 5/8" O.D. tubes permits the coil to drain completely through the water and drain connections and, in installations where sediment is a problem, the coil can be pitched in either direction. The simple removal of a single gasketed plate at each end of the coil exposes every tube, and makes thorough cleaning possible from either end.

The finned tubes are staggered in the direction of air flow, resulting in maximum heat transfer. Casings are standardized for easy installation.

Write for Bulletin No. R-50

AEROFIN CORPORATION

101 Greenway Ave., Syracuse 3, N.Y.

Aerofin is sold only by manufacturers of fan system apparatus. List on request.

A. I. Ch. E. candidates

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions. These names are listed in accordance with Article III, Section 3 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before July 15, 1959, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

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Miller, William D., *Tulsa, Okla.*
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Moss, Harold G., *Independence, Mo.*
Neil, Clarence David, Jr., *Pittsburgh, Pa.*
O'Brien, William Smithe, *Morgantown, W. Va.*
Overstreet, Wynton, *Brewton, Ala.*
Pearman, J. E. Gawain, *Kingsport, Tenn.*
Peterson, Charles H., *Woodside, N. Y.*
Rogers, Frank, *Norwalk, Conn.*
Rutherford, J. R., *Ottawa, Ont., Canada*
Schlotterback, Joseph M., *Wilmington, Del.*
Sewell, George M., *Birmingham, Ala.*
Shoemaker, F. Wells, *Princeton, N. J.*
Smith, Francis E., *Radnor, Ohio*
Soulis, Ronald Elliott-John, *Redlands Bch., Cal.*
Tarailo, Stanley D., *Windsor, Ont., Canada*
Tidwell, Edgar N., *Hopewell, Va.*
Trotter, Ide P., Jr., *Baytown, Tex.*
Voelpel, John W., *Peoria, Ill.*
Wiest, Donald G., *Rochester, N. Y.*
Wilburn, Norman P., *Richland, Wash.*

A fully electronic refinery is to be built in the Philippines, on Bataan Peninsula, by Standard Vacuum. The electronically controlled installation will contain field mounted instruments specially designed to withstand the corrosive tropical sea atmosphere of the site. The refinery is to be constructed by Swartwout Co. under an instrumentation contract said to be one of the largest of this type ever awarded by the petroleum industry.

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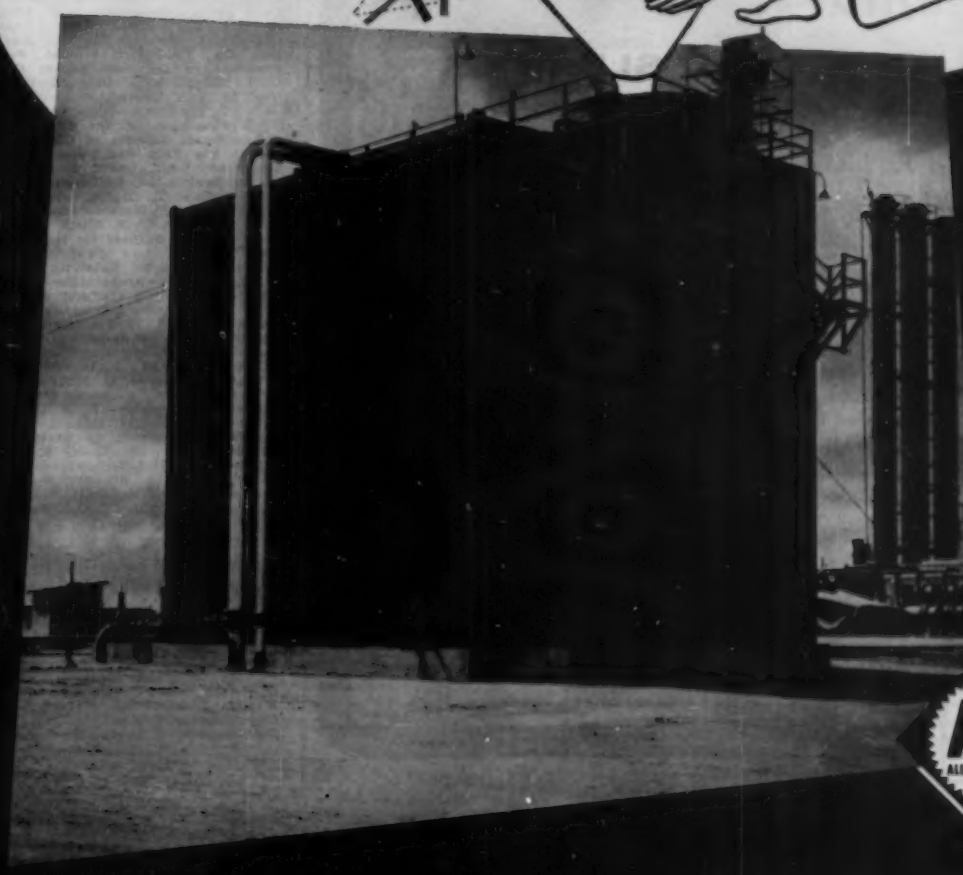
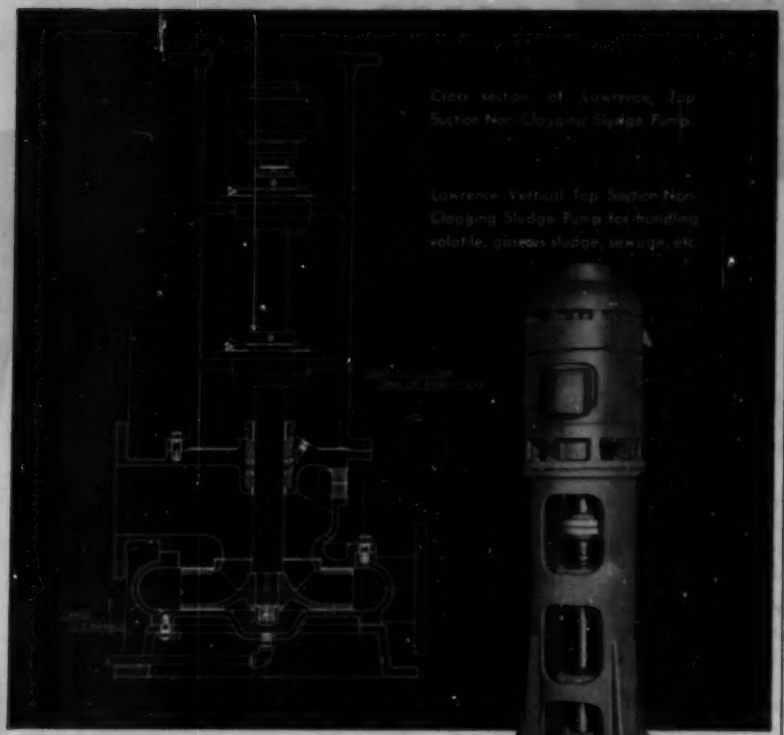


A-C ALLIS-CHALMERS


Cross section of Lawrence Top Suction Non-Clogging Sludge Pump
Lawrence Vertical Top Suction Non-Clogging Sludge Pump for handling volatile, gaseous sludge, sewage, etc.

PUMP
volatile
SLUDGES AND SLURRIES

...without clogging
...under a low net positive suction head (NPSH)
...without gas or vapor binding

The Lawrence Non-Clogging Top Suction Pump is designed specifically to handle volatile sludges and slurries. Large clearances through the impeller and casing completely prevent clogging. Volatile gases or vapors liberated at the impeller entrance (the point of lowest pressure), are pushed up and out of the way and can be vented back to the suction tank or exhausted to atmosphere.

This type of pump can operate with a very low Net Positive Suction Head (NPSH) and never become gas or vapor bound. It is made in all metals and alloys such as: — cast iron, bronze, stainless steel, Hasteloy, etc. — depending on the material pumped.

For further details on Lawrence Non-Clogging Slurry and Sludge Pumps write for Bulletin 206-4.

LAWRENCE PUMPS INC.
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future meetings

1959—MEETINGS—A.I.Ch.E.

• Storrs, Conn. August 9-12, 1959. Univ. of Conn. **A.I.Ch.E.-A.S.M.E. Heat Transfer Conferences.** Prog. Chmn.: M. T. Cichelli, Eng. Research Lab., DuPont, Wilmington, Del.

• Austin, Tex. Sept. 9-11, 1959. Univ. of Texas **Mid-West Conf. on Fluid & Solid Mechanics.** Co-sponsored by U. of Tex., **A.I.Ch.E.** & others. Tech. Chmn.: M. J. Thompson, U. of Tex. **Complete MS by June 1, 1959.**

• St. Paul, Minn., Sept. 27-30, 1959. Hotel St. Paul. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: A. J. Madden, Jr., Univ. of Minn. **Mixing**—J. Y. Oldshue, Mixing Equip. Co., Inc., P. O Box 1370, Rochester 3, N. Y. **Size Reduction**—J. W. Axelson, Johns-Manville, N. J **Missile Construction Materials**—B. M. Landis, Missile Div., Lockheed Aircraft, Palo Alto, Calif. **Physical Properties of Liquids**—S. E. Isakoff, DuPont Co., Eng. Dept. Expr. Sta., Wilmington, Del. **Molecular Engineering**—M. Boudart, Princeton U., Chem. Eng. Lab., Princeton, N. J. **Chemical Economics as a Unit Process**—M. H. Baker, 1645 Hennepin Ave., Minneapolis 3, Minn. **Process Control**—I. Lefkowitz, Case Inst. of Techn., Cleveland, Ohio. **Chemical Warfare**—Co-Chmn.: L. E. Garono & E. J. Gruen, Army Chem. Corps. Bldg. 250, Baltimore, Md. **Safety in Air and Ammonia Plants**—W. A. Mason, Dow Chem. Co., Midland, Mich. **Management of New Product Development**—L. B. Hitchcock, Consultant, 60 East 42 St., New York 17, N. Y. **Longitudinal Dispersion Effects**—J. R. Fair, Jr., Monsanto Chem. Co., Sta. B, Dayton 7, O. **Coalescence**—R. C. Kintner, Dept. Ch.E., Ill. Inst. Tech., Chicago 16, Ill. **Crushing Equipment**—E. J. Lyons, Turbo-Mixer Corp., 380 Madison Ave., New York 17, N. Y.: **Mixing Equipment**—E. J. Lyons, Turbo-Mixer Corp. **Student Program**—A. G. Fredrickson, Chem. Eng. Dept., U. of Minnesota, Minneapolis, Minn. **Selected Papers**—W. E. Ranz and H. S. Isbin, Dept. of Ch.E., U. of Minn., Minneapolis, Minn.

• Galveston, Texas, Oct. 30, 1959. Moody Convention Center. **14th Ann. Technical Meeting, South Texas Section, A.I.Ch.E.** Prog. Chmn.: R. D. Hornbeck, Alcoa, Rockdale, Tex.

• San Francisco, Calif., December 6-9, 1959. Sheraton Palace. **A.I.Ch.E. Annual Meeting.** Tech. Prog. Chmn.: C. R. Wilke, Div. of Chem Eng., Univ. of Calif., Berkeley, Calif. **Process Dynamics**—E. P. Johnson, Dept. of Chem. Eng., Princeton U., Princeton, N. J. **Operations Research**—R. R. Hughes, Shell Dev. Co., Emeryville 8, Cal. **Progress and Problems in Jet and Rocket Combustion**—C. J. Marsel, NYU, University Heights, New York 53, N. Y. **Thermal Recovery of Petroleum**—P. H. Poettman, Ohio Oil Co., Littleton, Colo. **Financing in the Chemical Industry: Fundamental Aspects of Chemical Engineering in the Pulp and Paper Industry**—J. L. McCarthy, Dept. Chem. Eng., U. of Washington, Seattle, Wash. **Turbulence and Turbulent Mixing**—T. Baron, Shell Devel. Co., Emeryville, Cal. **Electro-Chemical Engineering**—C. W. Tobias, Dept. Chem. Eng., U. of Cal., Berkeley, Cal. **Outlook for National Resources**—C. Meyer, U. of Calif., Berkeley, Calif. **Quality Criteria for Catalytic Cracking Stocks & Methods of Preparation**—W. W. Kraft, Lummus Co., 385 Madison Ave., N. Y. 17, N. Y. **Fundamental Concepts of Miscible Fluid Displacement**—P. H. Poettman, Ohio Oil Co., Littleton, Colo. **Financing in the Chemical Industry**—C. P. Neidig, White Weld & Co., 123 So. Broad St., Phila., Pa. **Selected Heat Transfer Papers**—J. G. Knudsen, Ch.E. Dept, Oregon State Coll, Corvallis, Ore. **Heavy Water Production Processes**—W. P. Bebbington, Dupont, Aiken, S. Car. Special Lecture Series: **Process Development by Statistical Methods** (all day Sunday, Dec. 6)—G. E. P. Box & J. S. Hunter, Statistical Rsch. Group, Princeton U., Princeton, N. J. **Student Program**—D. M. Mason, Stanford U., Calif. **Selected Papers**—M. Manders, Union Oil Co., Rodeo, Calif.

Deadline for papers: August 6, 1959.

1959—Non-A.I.Ch.E.

• New London, New Hampton, Meriden, (all) N. H. 12 weeks: June 15-Sept. 4, 1959. **Gordon Research Conferences** on fundamentals of engineering and science. Ref. to: W. George Parks, Conf. Dir., U. of Rhode Island, Kingston, R. I.

• Wash. D.C. Aug. 31-Sept. 2, 1959 Nat. Bur. Stds. **4th International Symposium on Free Radical Stabilization: "Trapped Radicals at Low Temperatures."** Ref. A. M. Bass, N.B.S., Washington, 25, D. C.

continued on page 121

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Waste treatment in a modern refinery

Every waste that occurs in a large modern refinery, from the water used in the refining process, to tank draw-offs and sanitary waste, as well as leakage from equipment, pump glands and pipelines, is being handled by a coordinated biological oxidation system at the recently-dedicated Bronte, Ontario, refinery of Cities Service Oil.

A flow of waste averaging 300 gallons per minute is gathered in a network of underground pipelines and led into one main sewer running to the treatment area. In a large rectangular basin, the oil separator, the waste is allowed to stand long enough for large quantities of oil to float to the top and for heavy material to settle to the bottom. Oil skimmed off the top is sent back to the refinery for processing, and the sludge pumped into a thickener, where water is removed and the residue dried for disposal.

From the oil separator, the water, which still contains dissolved chemicals and emulsified oil, is conducted into an equilibrium basin large enough to hold one day's flow of waste. Here, acids and bases can undergo partial dilution and neutralization, and suspended solids can be uniformly dispersed throughout the basin.

In the Bronte operation, three sets of pipes enter the equalization basin: one carries air, another steam, and the third leads in water from the separation tank. This third pipe is perforated and centrally located to distribute the incoming waste down the full length of the basin. Air is bubbled in to aid oxidation and to insure thorough mixing.

From this equalization basin, the water flows by gravity to a pump pit in the treatment building. If the waste is not completely neutralized at this point, it is adjusted in the pump pit. The neutralized waste is then brought up to 95°F in a heat exchanger. A solution of ferric sulfate is then mixed with the waste in one of two rectangular basins called flocculation-clarification tanks. The ferric sulfate breaks down the oil-and-water emulsion and joins with the oil to form heavy particles known as floc. At the same time, it collects all the finely suspended solid matter in the waste.

The primary aeration tanks contain a wide variety of bacteria. Main target of the bacterial action is the phenol compounds in the waste. In the secondary aeration tank, the bacteria are given further opportunity to feed without new waste being added.

Dow-Pac Filters

From the secondary aeration tank, the waste goes to a series of large cylindrical tanks containing sheets of corrugated plastic arranged in a "honeycomb" pattern. The water is pumped to the top and distributed over the honeycomb by means of rotating perforated pipes. The action of the Dow-Pac filters is similar to the aeration process except that, in this case, the bacteria adhere to the plastic sheets.

From these filters, the water flows into a sump. Some of the filtered waste is recirculated over the Dow-Pac units, while the bulk of it goes to the secondary clarifiers. Here all solid matter and excess bacteria settle to the bottom and are scraped away to hoppers. Floating material is skimmed to a slotted pipe on the outlet side. The clear water passes to a holding basin outside the building.

Care and feeding of bacteria

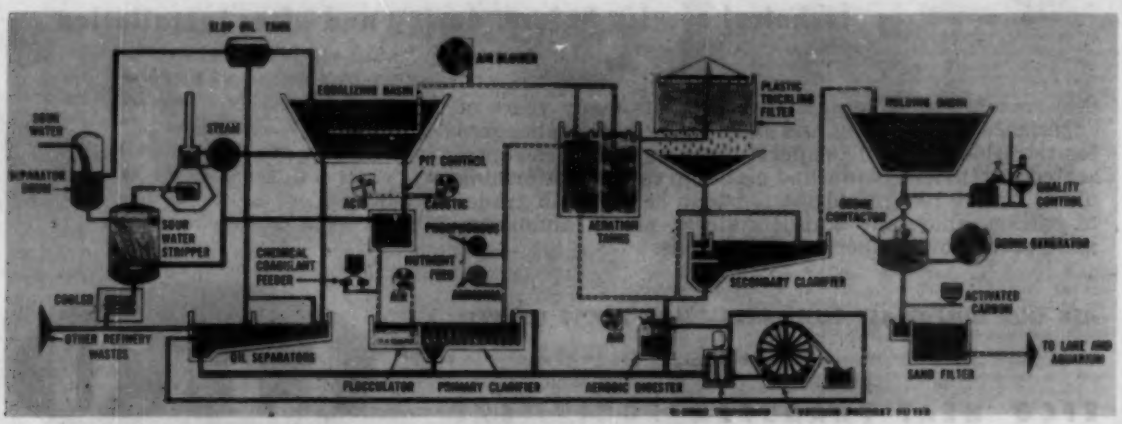
The bacterial sludge from the secondary clarifier is pumped to a concrete chamber in which a central wall divides the flow into two streams. One stream returns the sludge to the primary aeration tanks to maintain and replenish the bacterial population. When the supply of bacteria exceeds day-to-day requirements, the excess must be disposed of. This is done by sending the second stream in the concrete chamber to one of two tanks—the aerobic digesters. Here the bacteria are kept in constant motion, but are deprived of chemical food. As a result, they devour each other, the debris settles to the bottom and is conveyed to the sludge thickener.

In addition to the carbon and hydrogen present in refinery wastes, the bacteria also require phosphorus and nitrogen. These elements (in the form of phosphoric acid and anhydrous ammonia) are therefore added to the waste water just before it enters the primary aeration tanks.

Final purification

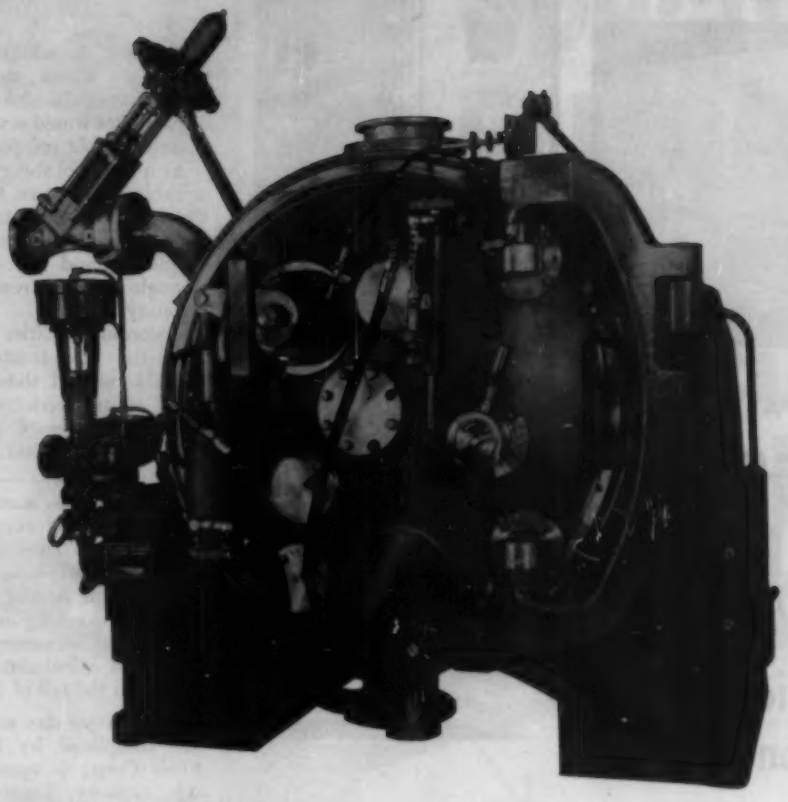
Clear water from the holding tank is pumped to a large stainless steel tank where it is mixed with ozone to oxidize any remaining phenolics.

continued on page 118



Details of the biological oxidation system at Cities Service Oil's new Bronte, Ontario, refinery.

The new Sharples C-41 Super-D-Hydrator



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The C-41 Super-D-Hydrator is the centrifuge that meets the stringent requirements of polyolefins and similar materials.

By applying high centrifugal force to a thin layer of crystals, and by controlling exactly the thickness of the cake, compaction is prevented and the crystal layer quickly gives up its liquid content . . . maximum use is made of rinse liquors in minimum time . . . because washing rinses are applied sequentially, separation of the mother liquor from various wash materials such as hydrocarbons, water, solvents, etc., is readily accomplished in the effluent piping . . . volatile materials are handled in the pressurized design without loss or hazard . . . controlled high speed unloading efficiently handles the pure, dry crystals and automatically prepares the basket screen for the next load . . . capacity on polyolefins is from 1 to 3 tons of dry solids per hour (up to 24 tons/hour in such materials as free draining ammonium sulphate).

The C-41 Super-D-Hydrator has been designed with the future in mind . . . and is proving today its exceptional performance on production lines in the field.

If high purity and increased capacity at minimum operating cost are requisites, let us tell you how the Super-D-Hydrator fits into your plans.

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Waste treatment

from page 118

The ozone, in addition to oxidizing phenolics, serves to disinfect the water: use of chlorine in the presence of phenolics would result in formation of undersirable compounds.

As a final polishing step, the water is subjected to two final treatments. Finely pulverized activated carbon is added to absorb any remaining traces of phenol, and the water is filtered through sand to remove any slight turbidity.

According to Cities Service, benefits from the new treatment plant are twofold: several thousand barrels of "lost" oil are recovered every month; and any danger of pollution in the environs of the plant is eliminated.

Construction has started on a $6 million dollar liquid oxygen plant by Air Products, Inc. The unit will distribute liquid oxygen, liquid nitrogen and liquid argon to the chemical, steel, and metal working industries. The 22 acre site, at Glassmere, Pa., according to present calculations, will be in operation in the fall of this year.

A 400-ton per day sulfuric acid plant just completed by Kermac Nuclear Fuels Corp., is operating above design capacity. Located near Grants, New Mexico, the unit is an integral part of the company's uranium mill. Sulfuric acid produced at the new unit is used in the mill's acid leach circuit.

Aluminum alkyls will be manufactured at a new plant to be built by Texas Alkyls, Inc., a company formed by Hercules Powder and Stauffer Chemical for that purpose. The million dollar plant, to be located near Houston, Texas, is scheduled for completion late this year. With an estimated capacity of one million pounds, the plant is designed for the manufacture of a range of aluminum alkyls, although initial production emphasis will be on aluminum trialkyls. Semi-commercial quantities are available from existing pilot plant facilities until start-up of the Houston plant.

Allied Chemicals' entry into the field of organic pigments takes place with completion of negotiations for acquisition of Harmon Colors, Haledon, N. J. firm. This division of B. F. Goodrich produces organic pigments for automotive finishes, paints, textiles, rubber, and plastics. Operations continue under the same management, supervised by Allied Chemicals' National Aniline Division.

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These huge plates, of Type 304 stainless steel, were made to Specification A-240 Grade S (ASTM A240-T). Each plate weighed over 49,000 pounds; one measured 461" x 179" x 2"; the other 451" x 184" x 2". Destined for a nuclear application, these plates were flame-cut and abrasive-cut to make two half-circles. The entire order totaled nearly 100,000 pounds.

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future meetings

from page 114

• **Berkeley, Cal. Sept 2-4, 1959. U. of Cal. Cryogenic Engineering Conference;** limited to technical aspects of field only below 150°K (—190°F). K. D. Timmerhaus, Secy. Cryo. Eng. Conf., Dept. Ch.E., U. of Colo., Boulder, Colo.

• **Portland, Ore. Sept. 10-12, 1959. Multnomah Hotel. Wood Ind. Conf.** sponsored by **ASME, FPRS & A.I.Ch.E. (Washington-Ore. Sect.)**

• **London, Eng., Oct. 30-33, 1959. Diamond Jubilee International Clean Air Conf. & Exhibition.** Info from Arnold Marsh, Dir. & Secy., National Soc. for Clean Air, Palace Chambers, Bridge St., London, S.W.1, England.

1960—MEETINGS—A.I.Ch.E.

• **Atlanta, Ga. Feb. 21-24, 1960. Hotel Biltmore. A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: F. Bellinger, Georgia Tech., 225 North Avenue N.W., Atlanta 13, Ga. **Kinetics**—C. D. Holland, Chem. Eng. Dept., Texas A&M, College Sta., Texas. **Pesticides**—(2 sessions) D. J. Porter, Diamond Alkali, Box 348, Painesville, Ohio. **Nuclear Feed Materials Processing**—D. S. Arnold, American Potash & Chem. Co. Henderson, Nev. **Petroleum, Turpentine, and Solvents; Rubber and Plastics Applied to Textile Fibers:** John Warner Chem. Div., Goodyear Tire & Rubber, 1485 E. Archwood Ave., Akron 16, O. **Bioengineering-Radioisotopes; Rockets and Missiles**—R. B. Filbert, Jr., Battelle Mem. Inst., 505 King Ave., Columbus, O. **Engineering Education; Mineral Engineering**—W. A. Koehler, West Virginia U., Morgantown, W. Va. **Fundamentals; Selling: By and To Small Plants**—J. T. Costigan, Sharples Corp., 501 5th Ave., New York 17, N. Y. **Filtration through Porous Media**—F. M. Tiller, Dean Coll. of Eng., U. of Houston, Houston 4, Tex. **Sterilization of Air & Food**—W. B. Harrison, Ga. Tech. **Air Pollution; High Pressure & High Temperature**—H. R. Batchelder, Batelle Memorial Inst., Columbus 1, O. **Mass Transfer Applications in Waste Treatment**—W. W. Eckenfelder, Manhattan College, Riverdale, N. Y. 17, N. Y.

Deadline for papers: Sept. 21, 1959.

• **Mexico City, Mexico, June 19-22, 1960. Hotel Del Prado. A.I.Ch.E. National Meeting**—Tech. Prog. Chmn.: G. E. Montes, Nat'l Petrochemical Corp., P.O. Box 109, Tuscola, Ill. **Chemical Engineering in Latin America**—John Mayurnik, Grace Chem. Co., 3 Hanover Square, New York 4, N. Y. **Petroleum and Natural Gas Processing in Mexico & Latin America**—F. W. Jessen, Dept. Petroleum Eng., U. of Texas, Austin Tex. **Financing International Projects; Optimization-Pitfalls & Potentials; Chemical Engineering Education in the Americas; Food and Biochemicals**—E. L. Gaden, Ch.E. Dept., Columbia U., New York 27, N. Y. **Minerals and Metals**—D. B. Coghlan, Foote Mineral Co., Berwyn, Pa. **Transfer Processes in Two-phase Systems**—S. G. Bankoff, Cal. Inst. Tech., Pasadena, Cal. **Distillation Equipment**—R. Katzen, 3735 Dogwood Lane, Cincinnati, O. **Cost Estimation. Selected Papers**—J. A. Samaniego, Shell Devel. Co., Emeryville, Cal.

Deadline for papers: January 19, 1960.

• **Moscow, USSR, June 1960. 1st Congress of International Fed., Automatic Control.** To cover areas of **Theory, Hardware & Applications of Automatic Control.** U.S. participation sponsored by American Automatic Control Council. Affiliated societies: **A.I.Ch.E., ASME, AIEE, IRE, ISA.** A.I.Ch.E. Chmn.: D. M. Boyd, Universal Oil Prods., Des Plaines, Ill. Completed papers by July 15, 1959.

• **Tulsa, Okla., Sept. 25-28, 1960. Hotel Mayo. A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: K. H. Hachmuth, Phillips Petroleum Co., Bartlesville, Okla. **Transport Processes in Petroleum Recovery; Natural Gas & Natural Gas Liquids**—R. L. Huntington, U. of Oklahoma, Norman, Okla. **Advances in Refinery Technology**—W. C. Offutt, Gulf R&D Co., P.O. Drawer 2038, Pittsburgh 30, Pa. **Petrochemicals**—C. V. Foster, Continental Oil Co., Ponca City, Okla. & H. L. Hays, Phillips Chem. Co., Bartlesville, Okla. **Piloting, or Why Buy the Restaurant When All You Need is a Meal**—R. E. Weis, Phillips Pet. Co., Bartlesville, Okla. & D. Popovac, Continental Oil Co., Ponca City, Okla. **Corrosion & Materials of Construction**—W. A. Luce, The Duriron Co., P.O. Box 1019 Dayton 1, O., & M. S. Worley, Black, Sivalls & Bryson, P.O. Box 1714, Oklahoma City, Okla. **Statistics and Numerical Methods Applied to Engineering**—R. L. Heiny, 2709 Jefferson, Midland, Mich. **Air & Ammonia Plant Safety**—L. T. Wright, **Refinery & Natural Gasoline Plant Safety, Processing Agricultural Products**—A. Ross.

continued on page 122

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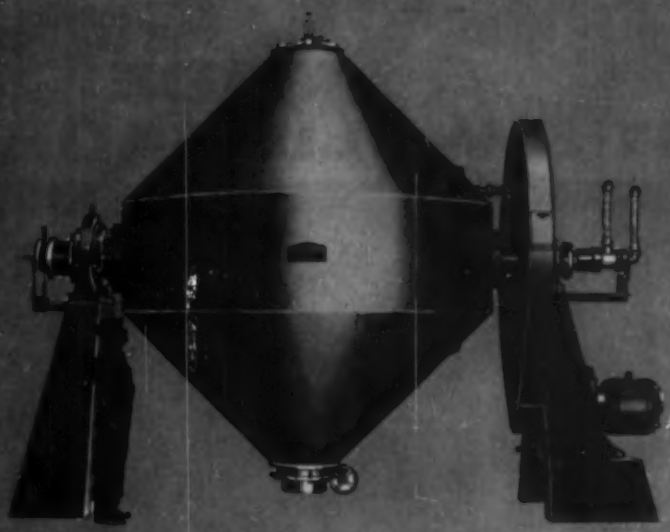

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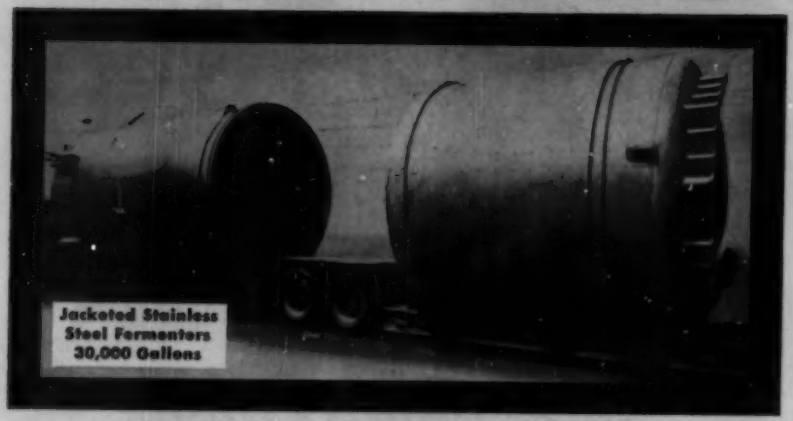

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future meetings

from page 121

Tex. Eng. Exp. Sta., Tex. A&M. Coll. Sta., Tex. **Area Industries. Chemical Reactions Induced or Modified by Radiation**—J. J. Martin, Ch.E. Dept., U. of Mich., Ann Arbor, Mich. **Conservation & Utilization of Water**—F. J. Lockhart, Ch.E. Dept., U. of So. Cal., 3551 University Ave., Los Angeles 7, Cal. **Foams**—C. S. Grove, Jr., Syracuse U., Syracuse 10, N. Y. & R. L. Tuve, U.S. Naval Rsch. Lab., Wash. 25, D.C. **Computers as a Management Tool**—R. Cziner, Grace Chem. Co. 3 Hanover Square, New York 4, N. Y. **Non-Newtonian Fluid Mechanics**—A. B. Metzner, U. of Delaware, Newark, Del. **Student Program. Selected Papers.**

Deadline for papers: May 2, 1960.

• Washington, D. C., Dec. 4-7, 1960. Statler Hotel. **A.I.Ch.E. Annual Meeting.** Tech. Prog. Chmn.: D. O. Myatt, Atlantic Research Corp., Alexandria, Va.

Tentative Program framework: **Chemical Engineering in Govt. Programs.** Agency Oriented: **Nuclear Energy, Health and Education; Agriculture; Foreign Assistance Programs; Resource Development; Utilization and Reclamation; Naval Warfare Technology; Land Warfare Technology; Chemical Warfare, and Basic Research.** Subject Oriented: **Doing Business with the Government; Fluid Particles and Aerosols; Combustion; Materials Deterioration; New Process Techniques; Unsteady State Instrumentation; Computer Control of Processing Units; Missiles and Rockets; Design Techniques for Very Large Systems; Information and Communication; Characteristics of Portable and Expendable Plants and Equipments.**

Deadline for papers: July 4, 1960.

1960—MEETINGS—Non-A.I.Ch.E.

• Adelaide, So. Australia. Feb. 16-19, 1960. Austral. Inst. Min. & Metall. **Wet Processing of Minerals & Industrial Products.** Deadline for 500-word synopsis, Apr. 30, 1959 (late return accept. from overseas) to: Aus. I.M.M. Sympos. Secy. c/o So. Austral. Dept. Mines, Osman Place, West Thebarton, Adelaide, S. A.

• London, England. Three days, Spring, 1960. International Symposium **Distillation: Fundamentals; theory & practice. Paper summaries** by June 1, 1959 to: Secy. Institution of Chem. Engrs., 16, Belgrave Square, London, S.W. 1, Eng.

1961—MEETINGS—A.I.Ch.E.

• New Orleans, La. Feb. 5-8, 1961. Jung Hotel. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: H. L. Malakoff, Petroleum Chem. P.O. Box 6, New Orleans 6, La. **Kinetics of Catalytic Reaction; Brainstorming Technical Problems; Petrochemicals—Future of the Industry on Gulf Coast; Future Processing Technologies in the Petroleum Industry; Education and Professionalism; Mathematics in Chemical Engineering; Liquid—Liquid Extractions; New Processes in the Area; Water from Sea Water; Materials of Construction. Evaluation of Research & Development Projects; Flow Through Porus Media.**

Deadline for papers: Sept. 5, 1960.

• Cleveland, O., May 7-10, 1961. Sheraton-Cleveland. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: R. P. Dinsmore, Goodyear Tire & Rubber Co., Akron 10, O.

Unscheduled Symposia

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.

Computers in Optimum Design of Process Equipment: Chen-June Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.

Solar Energy Research: J. A. Duffie, Director of Solar Energy Laboratory, Univ. of Wisconsin, Madison, Wis.

Hydrometallurgy—Chemistry of Solvent Extraction: G. H. Beyer, Dept. of Chem. Eng., Univ. Mo., Columbia, Mo.

Process Dynamics as They Affect Automatic Control—D. M. Boyd, Universal Oil Prods., Des Plaines, Ill.

Nuclear Chemical Plant Safety—C. E. Dryden, Ohio State U., Columbus, O.

Nuclear Reactor Operations—R. L. Cummings, Atomics International, P.O. Box 309, Canoga Park, Cal.

Operating Experience with the EBR-2—W. A. Rodger, Argonne Nat. Lab., P.O. Box 299, Lemont, Ill.

Drying—R. E. Peck, Ill. Inst. of Tech. 330 So. Federal, Chicago, Ill.

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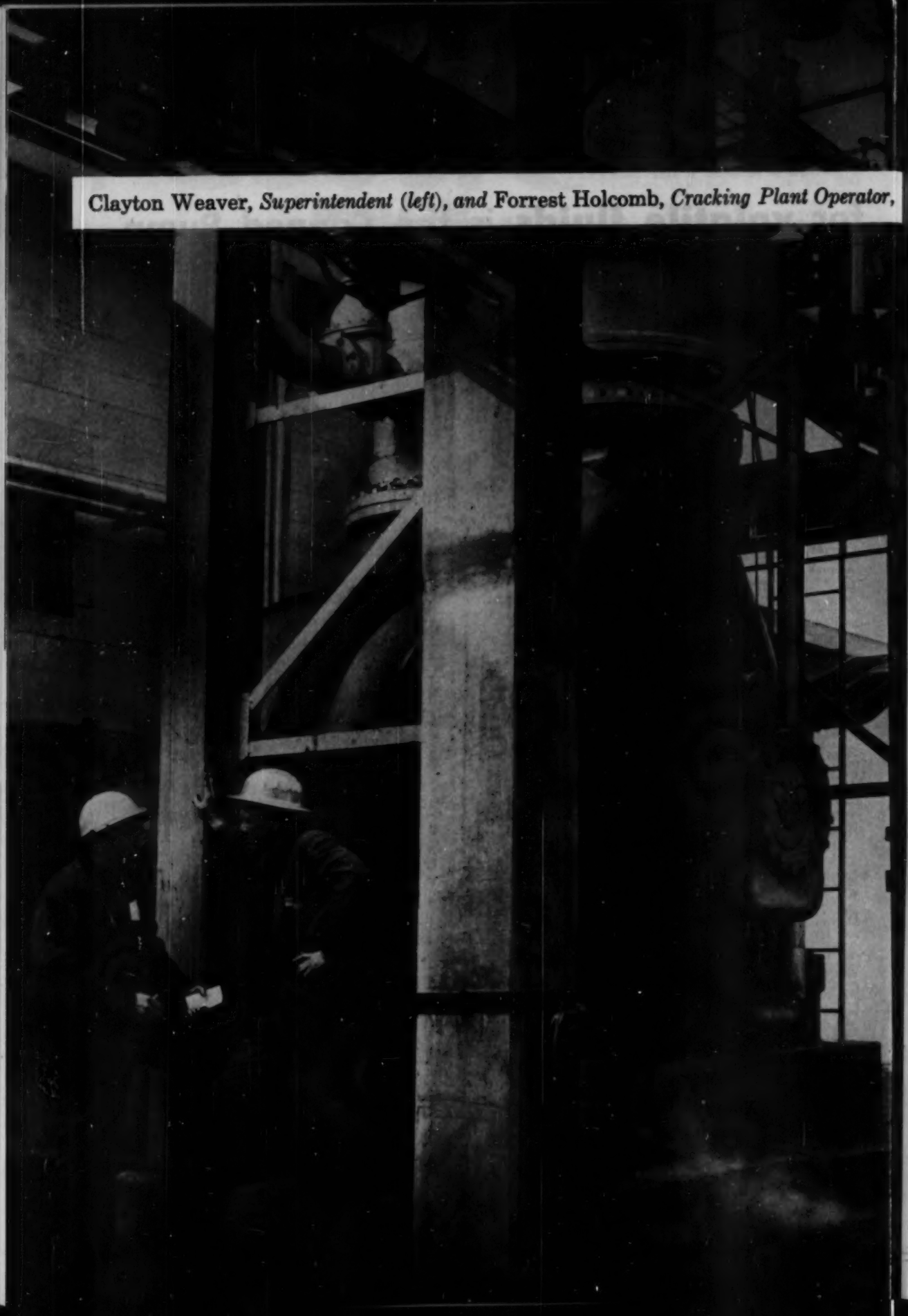

Clayton Weaver, *Superintendent (left), and* Forrest Holcomb, *Cracking Plant Operator,*

Leonard Refineries, discuss function of air supply in catalytic cracking and...

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Present at the Kansas City Meeting were Cesar O. Baptista and Ricardo Millares, president and vice-president respectively of the **Instituto Mexicano de Ingenieros Quimicos** (Mexican Institute of Chemical Engineers). Purpose of their visit was to finalize plans for the up-coming joint meeting of A.I.Ch.E. and I.M.I.Q. in Mexico City, June 19-22, 1960.

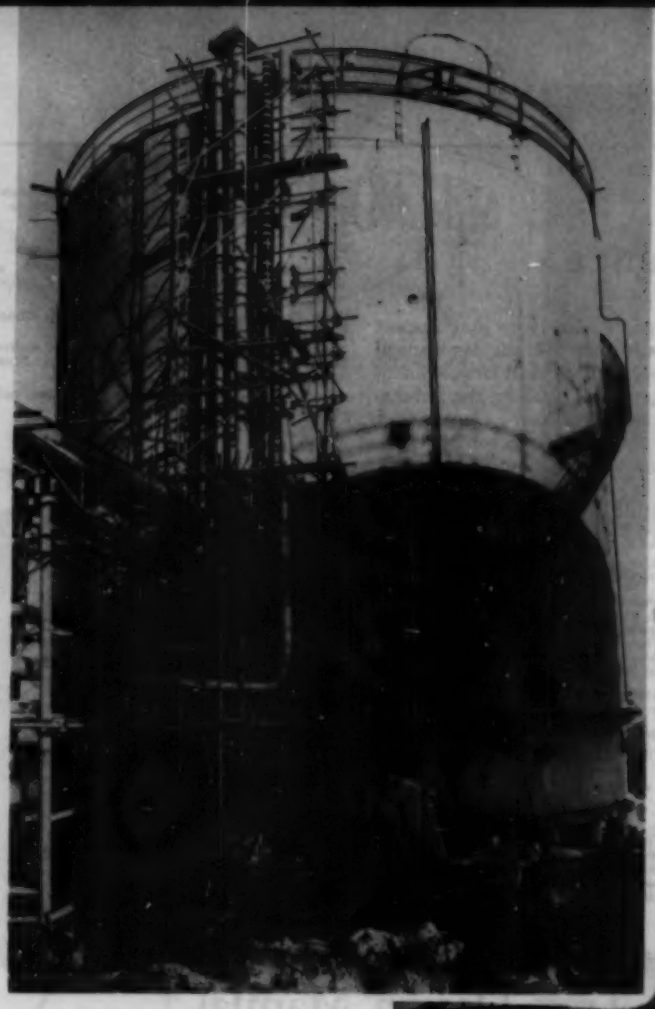
KANSAS CITY MEETING

R. P. Genereaux (right at lectern) addresses the Student Luncheon on Tuesday noon at the Kansas City Meeting. The luncheon was preceeded by a panel discussion on Careers in Chemical Engineering at which students had a golden opportunity to talk things over with a panel of industrial experts on recruiting practice and theory (see Scope, page 17).

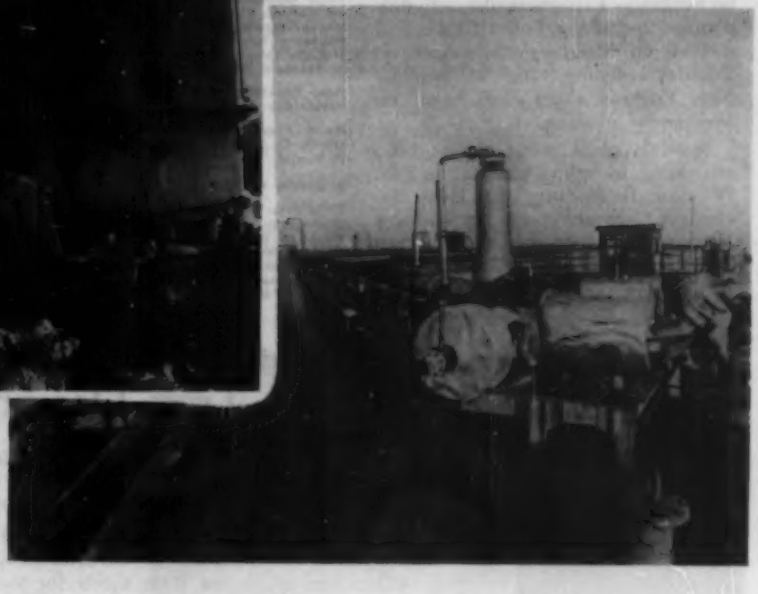
Panelists at the Sunday afternoon discussion on The Engineering Profession and the A.I.Ch.E. Left to right: A. H. Goeser, T. J. Mills, Roy Wheelock, President D. L. Katz, C. W. Nofsinger (chairman), and F. C. Fowler (general arrangement chairman).

The Get-Acquainted Party at Kansas City (Sunday evening) was the occasion for the cementing of old friendships and the making of new ones. This traditional pre-technical program event was well-attended and got the social program off to a good start.

cep camera



Part of Britain's recently started Methane Importation Scheme, this 90,000 cu. ft. insulated tank (left) will store liquid methane at —260°F. One of the largest aluminum tanks ever built in Britain, the new tank is all-welded, each weld has been radiographed. The 2,000 ft. aluminum pipeline (below), 10 inches in diameter, carries the liquid methane from a ship to the storage tanks. The shipping of liquid methane by tanker appears to be working out well.



Representatives of the United Engineering Trustees and the Turner Construction Co. sign the contract for the erection of the 18 story, $10 million United Engineering Center in Manhattan. (L. to r.) W. F. Thompson, UET; H. C. Bernhard, Shreve, Lamb and Harmon, Architects; A. Fletcher, UET; W. B. Ball, Turner; and E. K. Abbepley, Turner.

The world's largest speed increaser is now driving a 15,000 hp compressor in natural gas pipeline service. Built by Westinghouse Electric, the unit is being used by Texas Eastern Transmission Corp.

3rd Annual Heat Transfer Conference

The University of Connecticut, at Storrs, will be host to this summer's Heat Transfer Conference, sponsored jointly by the Heat Transfer Divisions of ASME and A.I.Ch.E. The mid-August date, 9-12, makes this an ideal opportunity to combine serious business with a three-day country vacation. For those who can bring the family, a program has been planned for the ladies, and it is understood that even baby-sitting facilities will be available. Extracurricular activities planned include a Buffet Picnic and a Play on Monday, a Banquet on Tuesday evening, and a "genuine New England shore clam bake" on Wednesday evening.

Several plant trips have been scheduled, including visits to the Pilot Radiator Laboratory, the Heat Exchanger Laboratory, and the Radiator Test Stands at the Canel Plant of Pratt and Whitney, and a trip to the nearby facilities of Combustion Engineering, where interested persons may inspect the Critical Facilities, the Mechanical Laboratory, the Material Development Laboratory, and, possibly, the Submarine Prototype Power Plant. (For most of these visits, proof of U. S. citizenship will be required.)

Technical Program

MONDAY, AUGUST 10

10:00 A.M.
SESSION NO. 1

Fluid Mechanics and Heat Transfer in Vertical Falling Film Systems, A. E. Dukler.
Measurements of Average Heat Transfer Coefficients for Helium and H_2 Flowing in a Smooth Tantalum Tube at High Surface Temperature, H. J. Newman.

Heat Transfer to Fluids Flowing with Velocity Pulsations in a Pipe, F. E. Romie.

Heat Transfer in Flow Through Rotating Ducts, C. Y. Kuo, H. T. Ida, J. H. Taylor, & F. Kreith.

SESSION NO. 2

Triangular Grids for Heat Flow Studies, G. M. Dusinberre.
Effect of Thermocouple Cavity Near Heat Sink Surface on Sink Temperature Distribution and its Measurement, J. B. Beck & H. Hurwicz.
Measurement of Thermal Conductivities of Gases at High Temperatures, R. G. Vines.
Thermal Conductivity of Some Mesamorphic Compounds, J. B. McCoy & L. S. Kowalczyk.

2:00 P.M.
SESSION NO. 3

Approximate Theory for Film Boiling on Vertical Surfaces, Y. Y. Hsu & J. W. Westwater.

Heat Transfer in Saturated Boiling, J. Chang & N. W. Snyder.

Populations of Active Sites in Nucleate Boiling Heat Transfer, R. F. Gaertner & J. W. Westwater.

Role of Surface Conditions in Nucleate Boiling, P. Griffith & J. D. Wallis.

3:00 P.M.
SESSION NO. 4

Radiant Interchange Within an Enclosure—Parts 1, 2, & 3, R. V. Dunkle & J. T. Bevans.
Heat Transfer from Pre-mixed Gas Flames in a Cooled Tube, D. W. Sundstrom & S. W. Churchill.

TUESDAY, AUGUST 11

9:30 A.M.
SESSION NO. 5

Variable-Density Single-Fluid Model for Two Phase Flow with Particular Reference to Steam-Water Flow, S. G. Bankoff.

Effect of Electrolytic Gas Evolution on Heat Transfer, P. O. Mixon, W. Y. Chon, & K. O. Beatty, Jr.

Two-Phase Flow Rates and Pressure Drops in Parallel Tubes, H. L. Poltz and R. G. Murray.
Theory of Local Boiling Burnout and its Application to Existing Data, L. Bernath.
Natural Circulation Loop Heat Transfer, J. H. Boggs.

SESSION NO. 6

Radiation Fin Effectiveness, J. G. Bartas & W. Sellars.

continued on page 130

An A.I.Ch.E. Technical Manual

Bubble-Tray Design Manual

prediction of fractionation efficiency

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TABLE of CONTENTS

Foreword	iii
I. Theory	1
II. Methods of Calculating Physical Properties	14
III. Research Results	25
IV. Efficiency Prediction Method	63
V. Methods to Increase Efficiency	72
VI. Multicomponent Systems	74
VII. Tray Design	76
VIII. Fractionation	76
IX. Sample Calculations	77
Notation	83
Literature Cited	87
Conversion Factors	89
Tables 1 through 6	89
Sponsoring Companies	94
Calculation Form Sheets	95

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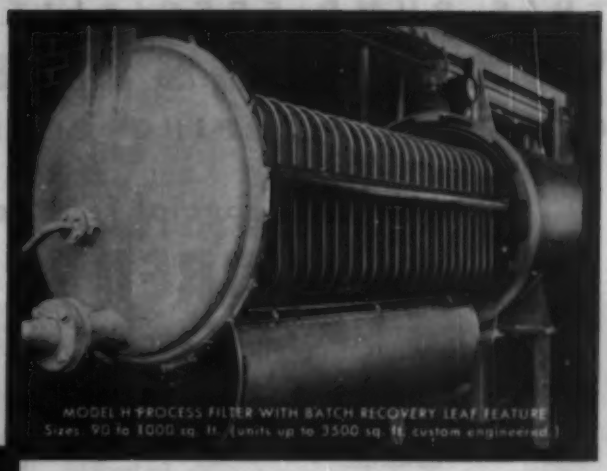

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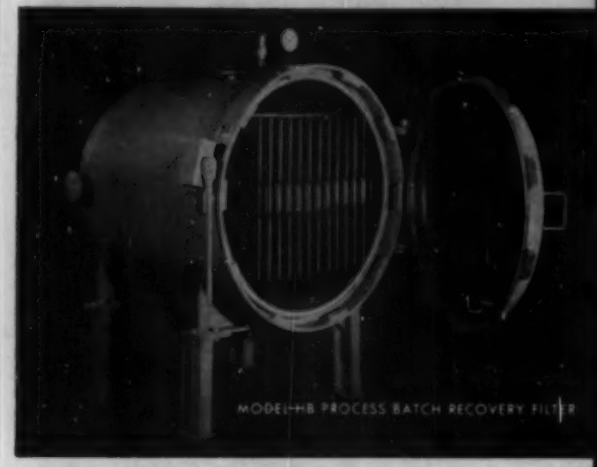

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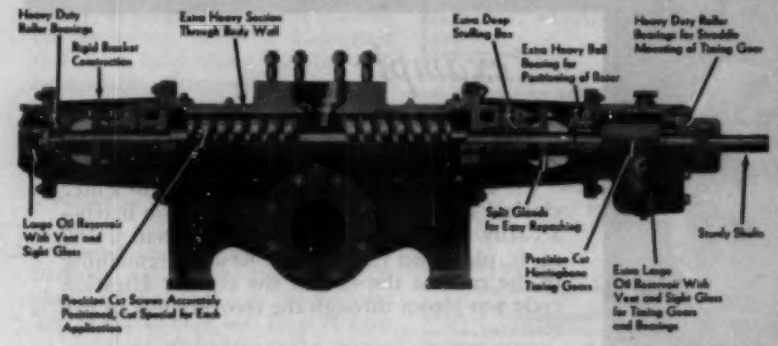
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Heat transfer

from page 128

Radiation Fin Efficiency for One-Dimensional Heat Flow in a Circular Fin, R. D. Chambers & E. V. Somers.
Spectral Characteristics of Fabrics from 1-23 Microns, R. V. Dunkle, P. Ehrenberg, and J. T. Gier.
Radiant Heat Transfer Through the Atmosphere. J. H. Chin & S. W. Churchill.

3:00 P.M.
SESSION NO. 7

Condensation on a Rotating Horizontal Disk, K. O. Beatty, Jr. & S. S. Nandapurkar.
Condensation of a Vapor in Presence of a Non-Condensing Gas, W. W. Akers, J. E. Crawford & E. H. Davis, Jr.
Condensation Inside a Horizontal Tube, W. W. Akers & H. P. Rosson.
Local Heat Transfer Coefficients and Pressure Drops for Refrigerant-22 and Condensing in a Horizontal Tube, M. Altman, R. H. Norris, & F. W. Staub.
Large Scale Plant Analysis of Colburn-Haugen Analogy, D. Q. Kern, J. F. Revilock, H. E. Hurlburt, D. R. Brake, & E. G. Lang.

3:00 P.M.
SESSION NO. 8

Freezing of a Growing Liquid Column, G. Horvay.
Temperature Distribution in Solids with Electric Heat Generation and Temperature Dependent Properties, R. P. Stein & M. U. Gutstein.
Transient One-Dimensional Heat Conduction Analysis for Heterogeneous Structure Including an Arbitrary Surface, M. L. Miller.
Digital Computer Solution for Transient Heat Transfer Problems, J. T. Anderson, J. M. Botts, & W. E. Koffel.

WEDNESDAY, AUGUST 12

9:30 A.M.
SESSION NO. 9

Conical Turbulent Boundary Layer Experiments and a Correlation with Flat Plate Data, W. S. Bradfield.
Stream Slip-Theoretical Prediction from Momentum Model, S. Levy.
Magnetohydrodynamic Effect Upon Heat Transfer for Laminar Flow Across a Flat Plate, R. D. Cess.
Laminar Transfer from Isothermal Spanwise Strips on a Flat Plate, H. H. Sogin.
Heat Transfer to Laminar Flow in Circular Tube with Arbitrary Circumferential Heat Flux, W. C. Reynolds.

SESSION NO. 10

Determination of Core Dimensions of Cross Flow Gas to Gas Heat Exchangers, P. S. Lykoudis & R. M. Shastri.
Heat Transfer Rates for Parallel Flow of Liquid Metals Through Tube Bundles, O. E. Dwyer, & P. S. Tu.
Assessment of Heat Exchanger Data, S. K. Jensen.
True Temperature Difference in a 1-2 Divided Heat Exchanger, D. L. Schindler & H. T. Bates.
Organization of Heat Exchanger Program on Digital Computer, J. J. Taborek.

2:00 P.M.
SESSION NO. 11

Conductive Heat Transfer in a Re-entry Body Analysis of Computational Methods and Their Reliability, H. Hurwicz & M. S. Klamkin.
Heat Transfer from Yawed Cylinders in Rarefied Air Flows, L. V. Baldwin, V. A. Sandborn, & J. C. Lawrence.
Influence of Free Stream Turbulence on the Local Heat Transfer from Cylinders, R. A. Seban.
Unsteady Turbulent Heat Transfer in Tubes, E. M. Sparrow & R. Siegel.

3:00 P.M.
SESSION NO 12

Heat Transfer with Molecular Sieve Adsorbent: 2—Heating with Longitudinal Finned Tubes. B. D. Phillips.
Heat Transfer with Molecular Sieve Adsorbent: 1—Effective Thermal Conductivity. B. D. Phillips & P. W. Leavitt.
Heat Transfer in Baffled, Jacketed, Agitated Kettles, G. Brooks & G. J. Su.
Heat Transfer to a Single Cooling Tube in a Moving Bed Reactor, D. J. Loudin & K. O. Beatty, Jr.

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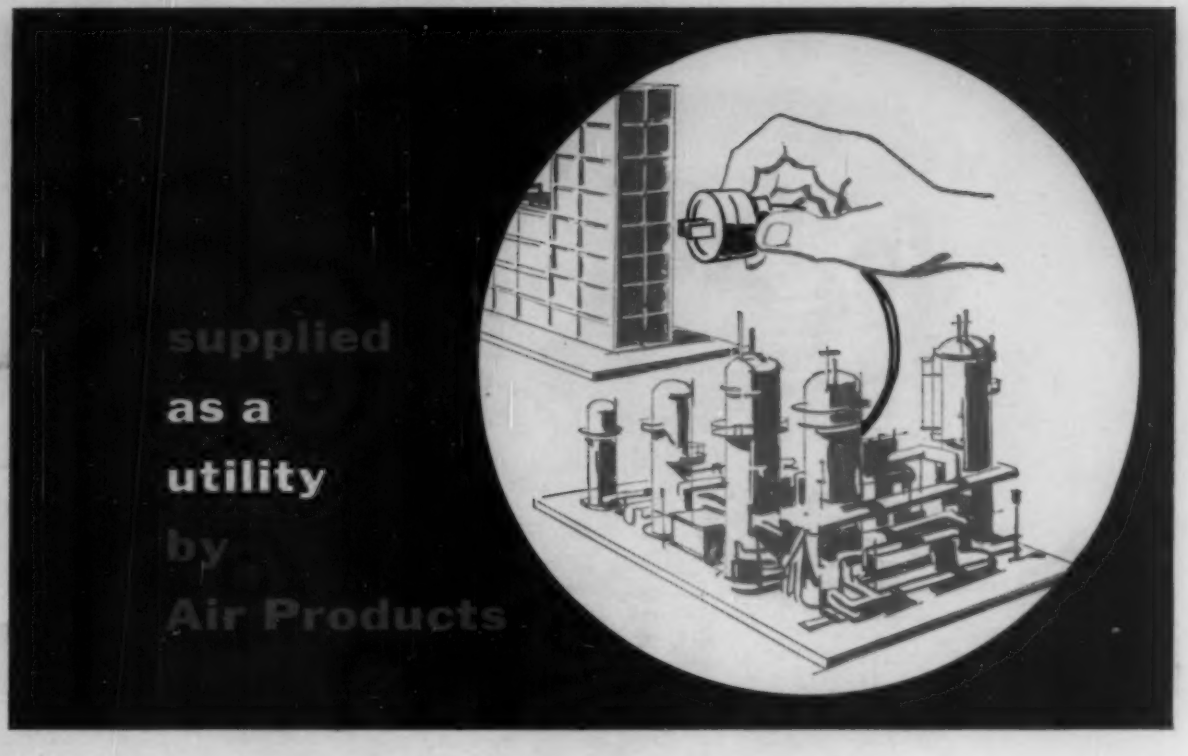

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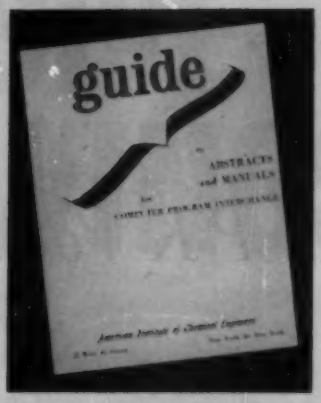
CEP

COMPUTER PROGRAM abstracts



This now available "Guide to Abstracts and Manuals for Computer Program Interchange" gives general information and examples on how to prepare and submit the material.

Continuing what will now be a regular feature of CEP, here are four more abstracts of industrial computer programs. Already the reaction has been more than encouraging. In fact, results to date prove that engineers today have a strong professional interest in all practical matters pertaining to the use of computers in their work.

To make it easier for the computer information interchange program to function smoothly, the Machine Computation Committee has prepared a *Guide* for all those interested in participating in the program. The *Guide* (see above right) contains all the "how-to" information on preparing abstracts and manuals for any computer program, is available from the Machine Computation Committee, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Once again the Committee wishes to emphasize the three rules for participation in the interchange program:

1) Abstracts submitted for publication must follow the form published in *CEP* (January, 1959) and in the *Guide*.

2) Abstracts must be sent to the Machine Computation Committee c/o A.I.Ch.E.

3) All questions relating to published abstracts must be sent to the Committee c/o of A.I.Ch.E. in New York.

Tarner Method

R. W. Donovan, H. D. Eddy and D. D. Smith
Standard Oil Company of California
San Francisco 20, California

Description: This program predicts gas drive reservoir oil and gas production vs. pressure performance for varying reservoir properties by the Tarner method. The effect may be shown of water encroachment, water injection, foreign gas injection, produced gas reinjection, natural gas cap and pressure maintenance.

Computer: IBM 704, 8K.

Program language: Fortran.

Running time: Fifteen to sixty seconds per case, including card loading time.

Comments: Solution scheme is basically that of the original Tarner method, with some refinements explained in the program write-up. P-V-T and K_g/K_o data input limit is 50 values per variable. Very complete output is prepared which includes all input data and results of calculations. Curve plotting routine input may also be program prepared.

Availability: Presently being used for production, but a complete program write-up will not be available until early May.

Bubble cap tray design (Two programs)

Arthur G. McKee & Co.
Oil Process Department
Cleveland 1, Ohio

Description: These programs are designed to calculate the tray hydraulics for bubble trays using the Davies correlation. Other than a tray lay-out no additional input data are required for this program than would be readily available to the engineer.

Various input arrangements can be handled by the programs. Either single cross flow trays, split flow trays, or cascade trays may be specified. Only round bubble caps spaced on either triangular or inline pitch can be handled by use of the programs. By suitable modifications of input data the second program handles tunnel cap trays.

Computer: IBM 650 with alphabetic attachments.

Program language: Bell L_2.

Running time: The machine running time varies between three and four minutes.

Availability: A program manual has been written and can be made available for publication should sufficient interest develop.

Regression analysis

Standard Oil Company of California
K. K. Bailey, Murray Berg, D. C. McGowan, L. G. Painter, E. J. Thompson

Description: The program performs a multiple regression and correlation analysis. The maximum size problem is 39 independent and one dependent variables. Back solutions are obtained to six significant figures.

Computer: IBM 704, 4K or larger.

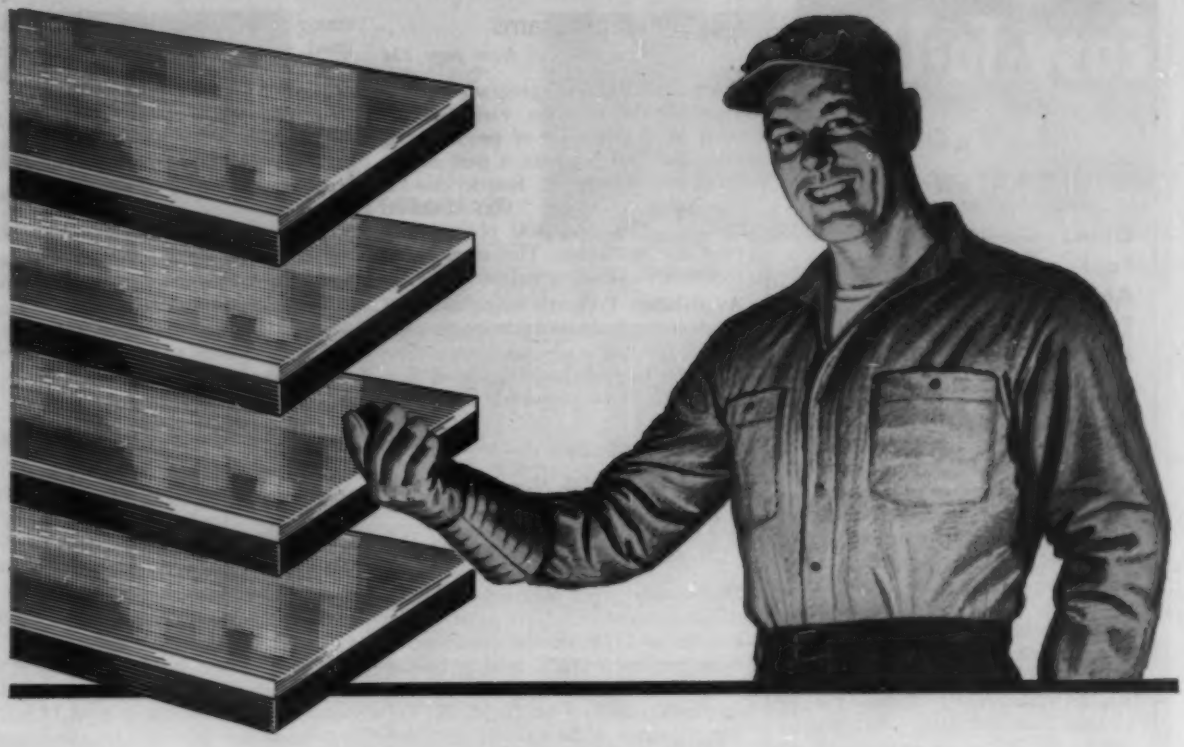
Programming Language: SAP and FORTRAN II.

Approximate Running Time: For a *maximum* size problem:

FORTRAN Assembly—5 minutes.
Input Editor Run—8 minutes.
Regression Run—10 minutes.

Comments: The input editor portion transforms the observed variables, V_i, into function variables $X_j = f(V_i)$, which are the actual regression vari-

continued on page 136



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Computer programs

from page 134

ables. A FORTRAN program to compute all the function variables, X_j, used in a given set of problems, is compiled and becomes a part of the input editor program. Restrictions for the input editor are 1,000 observed variables, V_i, and 400 observations of these variables. The number of function variables is unlimited.

Availability: Presently being used for production. Preliminary write-up completed but not ready yet for distribution. An English language level flow diagram will be prepared.

Piping Flexibility

E. I. du Pont de Nemours & Company, Inc.
Engineering Department
Programmed by H. E. Obermann

Description: The program calculates the movement of a restrained piping system, and the stresses produced in each member when heated to operating temperature. It is based on the methods published by the M. W. Kellogg Company, "Design of Piping Systems", 2nd edition, 1956, with slight modifications. Moments and forces acting on the piping system are calculated, using inversion and reinversion of a 6 x 6 matrix. The requirements of the ASME Unfired Pressure Vessel Code are complied with. The input data form specifies the pipe size, temperatures and pressures, Poisson's ratio, and Young's modulus. The piping layout is described by the coordinates of the intersections of center lines of all straight runs, and by the radius of each bend. The program produces an edited tabulation of the stresses, resultant bending moments, forces, deflections, and rotations of every member in the system.

Computer: Univac I, 9 servos.

Program language: GP Compiler, C-10 code.

Running time: 0.6 to 1.0 minute per member.

Comments: The program will handle a pipe system with any number of branches; it will not handle loops, double skews (oblique to the three coordinate grid), or branches on branches.

Availability: A program manual is being written according to A.I.Ch.E. standards for internal company use and will be submitted for publication when completed.

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industrial news

New paraffin wax plant

Just-completed unit at Atlantic Refining's Philadelphia works uses Texaco's MEK solvent dewaxing process.

Costing approximately $18 million, a new plant of Atlantic Refining in Philadelphia has a capacity of some 216 million annual pounds of low-oil content paraffin waxes. The process used was based on Texaco Development's MEK (methyl ethyl ketone) solvent dewaxing method.

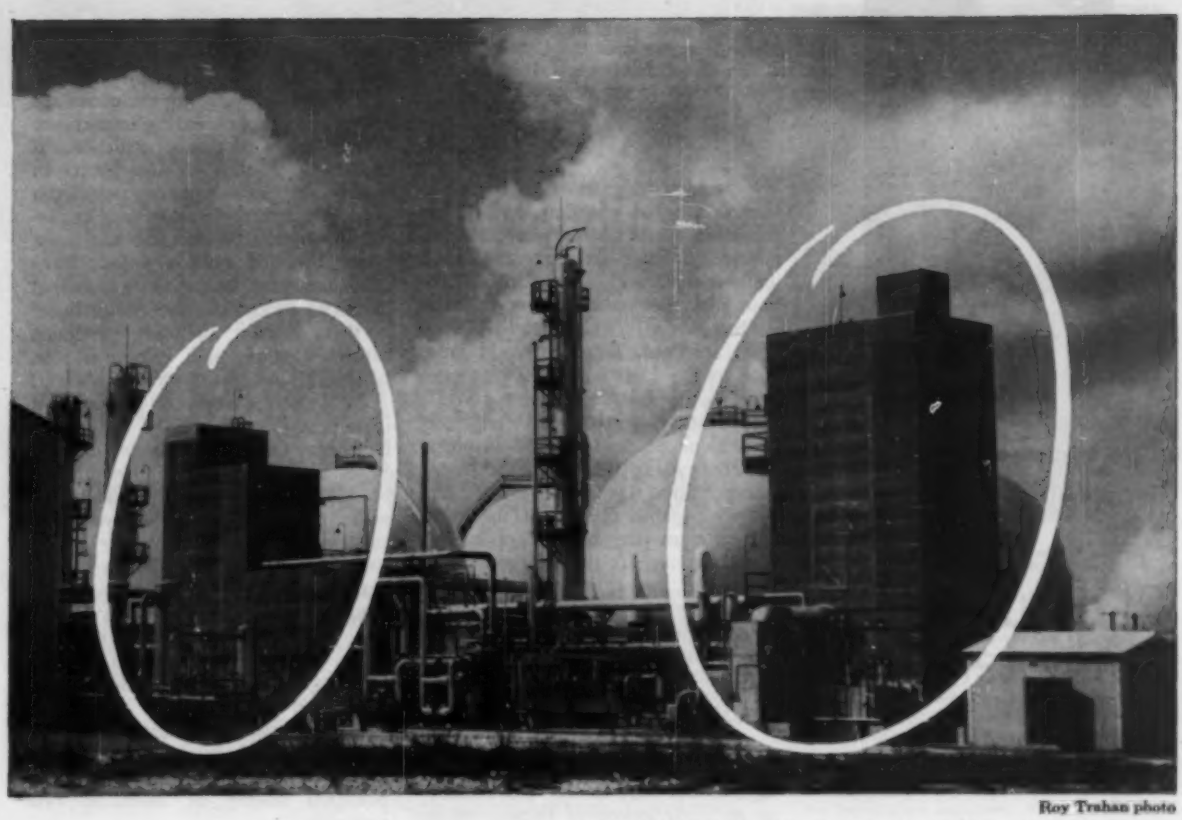
Unusual feature of the design (by Badger Manufacturing) is the filter section where the wax and oil separation takes place. The specially-designed filters here, with drums 11 ft. in diameter and 20 ft. long, are said to be the largest in use in the petroleum industry.

The chilled wax slurry flows into the filters by gravity, with the dewaxed oil and solvent being pulled through the filter cloth by vacuum. Subsequently, the cake is diluted and put through repulping and refractionating operations for further removal of oil and other undesirable components.

Prior to each stage of filtration, the wax mix is chilled in a newly-designed system of exchangers and chillers. The section consists of a battery of double-pipe, scraped-surface exchangers and double-piped, scraped surface chillers arranged in two parallel banks with the drive ends facing each other.

The first German power reactor is expected to go critical in early 1961. Part of an expected rapid increase in the use of atomic power commercially in Europe, the facility is a 15,000 ekw boiling water power reactor. To be located at Kahl, near Frankfurt, West Germany, it will be built for Reinisch-Westfalische Elektrizitatswerke A. G. of Essen. Mallory-Sharon Metals will supply zirconium for the project, which will be supervised by GE.

A tall oil refinery processing 40,000 tons of crude tall oil will be constructed by Arizona Chemical. Present plans call for the new facility to be completed by the summer of 1960. The nine acre site is located adjacent to International Papar Company's sulfate mill in Springhill, Louisiana. The firm is a jointly owned subsidiary of International Paper and American Cyanamid.



Roy Trahan photo

Part of the Petroleum Chemicals Inc. installation at Lake Charles, La., showing the two Air Liquide units mentioned below.

Low-temperature separation at its best!

The large and complex project of Petroleum Chemicals Inc. and Calcasieu Chemical Inc., at Lake Charles, La., is typical of the wide scope and adaptability of low-temperature gas separation.

At the P.C. ammonia producing plant, a raw hydrogen feed stream containing platformer, butadiene, hydroformer and ethylene cracking off gases, is treated by an Air Liquide low-temperature nitrogen scrubbing unit. It is the largest of its kind to handle such a variety of feed streams.

The resulting ammonia synthesis gas, in correct hydrogen-nitrogen ratio and containing less than 20 ppm of total impurities (CO + Oxygen), is rated at the ammonia equivalent of 310 tons per day.

Pure nitrogen for the ammonia and for the liquid nitrogen scrubbing is produced in an Air Liquide air separation plant rated at 100 tons of oxygen per day. Both units will maintain the same product purities even at 60% capacity.

The Calcasieu Chemical plant, with an Air Liquide 180-ton-per-day oxygen unit, uses the gas directly to manufacture ethylene oxide. This unit, differing from the conventional design, is a low-pressure regenerator type producing at the required pressure of 225 psig using liquid oxygen pumps. This special Air Liquide cycle eliminates the problems of oxygen compressors and results in a safe plant with lower power consumption and good process control.

Behind these achievements is more than half a century of design and engineering experience which can help you solve your own low-temperature problems.

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- Air separation—oxygen, nitrogen, and rare gases.
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Indian God of Peace, giant memorial statue, stands watch over the Gateway to the Great Northwest. This 39-ft. high work is in the concourse of the St. Paul City Hall.

St. Paul in September

ALBERT P. EARLE
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St. Paul, Minn.

St. Paul has evolved in little more than a century from a pioneer Indian campsite into one of the largest cities in the country. A dynamic community, the capital city of Minnesota is part of the Twin City metropolitan area with a total population of over one million. Visitors to the National Meeting in September will find St. Paul a friendly place, a favorite convention spot and meeting place for hundreds of groups each year. There's always something doing in the Twin Cities. A noted vacation land, it has 22 lakes, many parks, several golf courses, boating, fishing, year round amusements and recreation. Take your pick. Between sessions, that is.

One gets a feeling of great vitality from St. Paul. This is due in great part to the fact that it is "the gateway to the great northwest". While the economy is no longer completely dependent on trade and transportation, the city is still a key (and busy) transportation center. The northernmost navigable portion of the state, largest river port in the upper midwest, the nation's third largest trucking center, home base of one of the nation's four transcontinental airlines, St. Paul possesses, by volume, one of the largest air terminals in the United States.

Industrial now

The state of Minnesota just recently turned the corner from a primarily agricultural state to one with industry as its main source of income. Major firms with plants located in the Twin Cities are: Ford Motor Co., Brown & Bigelow, Remington-Rand Univac, Swift and Armour (packing house products), H. B. Fuller (industrial adhesives), Toni (toilet preparations), West Publishing.

Minneapolis is one of the world's leading flour milling centers. Most of its milling companies have important research and development departments. General Mills does approximately half its business in research, while two of its biggest activities in the chemical line are soybean oil processing and polyamide resin products.

The state's expanding industries are reflected in the increasing importance of the Twin Cities as a petrochemical center. St. Paul is an area leader in production of refined petroleum products, and agricultural and industrial chemicals. Within the last three years, over 50 million dollars have been expended in the city's principal chemical industrial district of Roseport. Refineries, ammonia products, carbon dioxide, and sulphuric acid plants are among those recently built.

At present, crude oil is brought from Canada to supply the Great Northern Oil Co. refinery at Pine Bend, and Northwestern Refining at St. Paul Park. These firms now consume 50 percent of the crude oil capacity. Gasoline and other petroleum products are delivered by Standard Oil and Great Lakes Pipeline; natural gas is supplied by Northern Natural Gas from southwest fields. The Williston Basin of the Dakotas is expected to add further to natural gas pipelines.

Another factor adding to the bright outlook on industrial growth is the near-by lignite deposits, a great potential source of chemical raw materials.

Area chemical industry

St. Paul is the home of Minnesota Mining and Manufacturing Co. (3M). Largest chemical industry in the area, 3M makes adhesives, abrasives, recording tapes and the more recently developed fluorochemicals. Research goes on at the Central Research Center. 3M claims to have the world's largest oven at its coated abrasives plant—it measures 976 feet.

continued on page 142

Aerial view of downtown St. Paul shows the principal shopping and business district. A $100,000,000 modernization program is now underway to develop outlying areas of the metropolis on the Mississippi.

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*Prices quoted are for domestic shipment only.

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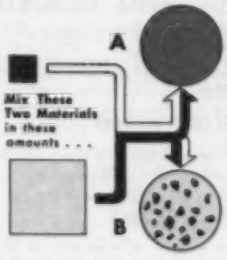
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St. Paul

from page 140

The company was also involved in the Rocky Mountain Power Group to investigate practical applications of atomic power in the area.

Lithium Corp. also has its headquarters in the Twin Cities, producing lithium salts and derivatives. Koppers Co. has as its principal activity manufacturing coal and coke by-products, with a by-product tar processing facility.

Also located in the Twin Cities is Minneapolis-Honeywell Regulator Co., an engineering company and manufacturer for the chemical industry, and supplier of different type instruments to process industries.

Plant tours are held for groups by the Local Chamber of Commerce. More on this later.

Education and culture

The University of Minnesota in Minneapolis is one of the country's top educational institutions, has a total enrollment of nearly 30,000. The University's Engineering and Physical Science graduates are on the preferred list of industry throughout the nation. St. Paul itself has fifteen technical and professional schools, and eight colleges and universities.

The city's combination heritage from Scandinavian and other European countries, and American Indian, is pointed up by the 39 foot statue, "Indian God of Peace", which stands guard over the St. Paul City Hall. Created by the Swedish sculptor, Carl Milles, in Mexican onyx, the memorial is a powerful example of community art.

On the lighter side, Municipal Auditorium, in the St. Paul business district, is a center for entertainment of all types from ice revue to theatre. Attention baseball fans:

Addition to the sports scene is the $4½ million Metropolitan Stadium, built at major league size. It houses the Minneapolis Millers of the American Association. St. Paul, too, has a new baseball park, Midway Stadium.

To get down to essentials, inquiries tell us that food-wise, the Twin Cities has its quota of smart supper clubs and good restaurants. Particularly noteworthy are the lake trout, walleye pike, Minnesota steaks and true Scandinavian smorgasbord. Especially recommended by our area informants for good dining and entertainment, are the Criterion, Coleman's, and in Minneapolis, Shiek's (Calypso music combined with good food), and Charlie's Cafe.

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Nuclear Engineering, Part I: The first volume from the first nuclear engineering congress, held at Ann Arbor, contains articles on the metallurgy of zirconium, beryllium, thorium, uranium, heat transfer studies in the nuclear field; and articles on reactors including the Swedish reactor; chlorination of aromatics under gamma radiation; gamma-ray polymerization of styrene and methyl methacrylate. 280 pp., paper bound; $3.00 to members, $4.00 to nonmembers.

Nuclear Engineering, Part II: the second volume from the first nuclear engineering congress, held at Ann Arbor, continues the technology of the first volume — reactors, analog computing techniques for reactor analysis, evaluation of reactor coolants, metallurgy, waste disposal, radiation damages and effects on structural materials. 259 pp., paper bound; $3.00 to members, $4.00 to nonmembers.

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Nuclear Engineering, Part IV: Containing papers sponsored by the A.I.Ch.E. at the second nuclear engineering and science congress, in Cleveland, this volume of 206 pages contains more on reactors, solvent extraction systems, economic design of power packages, neutron flux in critical assemblies, engineering design, reactor site selection, metallurgy, etc. Paper bound; $3.00 to members, $4.00 to nonmembers.

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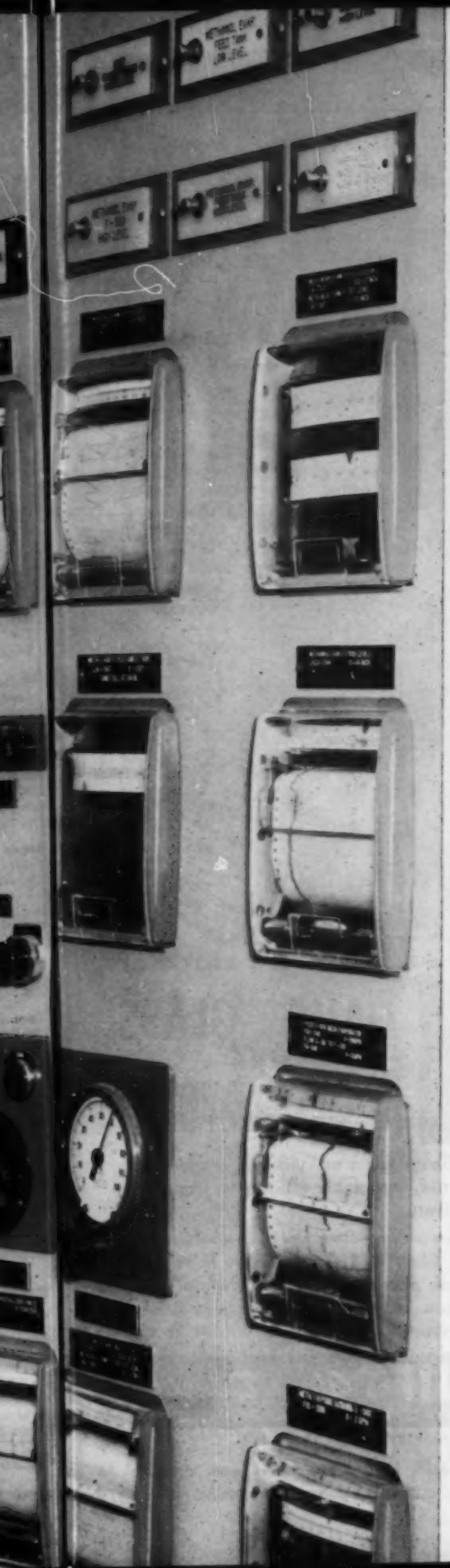

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Tyler Award to Zenz

Frederick A. Zenz received the Tyler Award from the **New York Section** this year. Dr. Tyler made the presentation to Zenz at the May meeting in recognition of his paper, *A Theoretical-Empirical Approach to the Mechanism of Entrainment from Fluidized Beds*. The work developed a means of calculating the rate of entrainment of solids from commercial-size continuously-operating fluidized beds from the combined results of a theoretical and empirical approach which, through different channels, arrived at the same fundamental mechanism.

The citation is given annually in honor of Stephen L. Tyler, past secretary of the Institute, to that member of the section who, in the opinion of the judges, made the most significant contribution to the literature of chemical engineering. Entries were restricted to articles or papers published during the previous year in a period-

ical serving the profession. Zenz, who is manager of the process department, Associated Nucleonics, Inc. (Stone & Webster Engineering), co-authored the paper with Nicholas A. Weil. It appeared in the *A.I.Ch.E. Journal* in December, 1958.

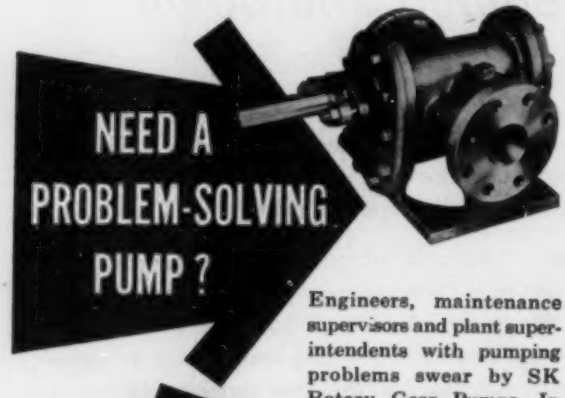
Engineering education

On the same New York program, a 3-man panel discussion aired conflicting views on engineering education. Within five to ten years, according to Charles M. Thatcher, head of the Chemical Engineering Department at Pratt Institute, chemical engineers will have to have a working knowledge of physics, chemistry and math. He emphasized the need for general as opposed to specialized curricula. Thomas Smylie, manager of manufacturing and distribution at Ethyl Corp., on the other hand, while he stressed the importance of chemical engineers in process design and plant technical service, said that companies hire engineers to get answers to problems. Management looks primarily for competence in chemical engineering science. Moderator was Ray Fremed.

Engineer's motivation, student awards

"You get up mornings and go to work because you would rather do that than anything else," claimed Max B. Skousen, management training specialist, speaking at the **Southern California Section's** (*R. D. Sheeline*) April meeting on "A New Approach to Motivating Engineers." Skousen explained that while one might enjoy a day's fishing more than a day at his desk, requirements for food, clothing and shelter, plus the desire to be able to do some fishing, results in a person going to his office each day. This is

continued on page 148



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from page 146

obviously his best way to have the basic necessities, plus the means to do other things he enjoys. The key to Skousen's method is to make people choose to do better by exploiting the fact that we all can be motivated to achieve pride and recognition for our work.

Pressure is what makes us tick. Negative pressure, such as threats or punitive measures, are effective only to a point. Positive pressure, like that exerted automatically on a man in business for himself, where he tackles his work because he wants to, is far more effective. We must show people that they have to do certain things to attain recognition and pride in their work. Knowledge and intellect must be applied toward showing the relativity of various aspects of performance. If we could collect the facts to know what people are doing, how much of their time is spent in productive work, talking, blue sky thinking, or waiting for others, we would have power in our hands to motivate people. These facts can be obtained by five minutes effort a day. The device to use is the concept of sampling. If you'd like to test this concept, try it on the Q.T., but promise yourself never to use information obtained that way! To obtain a favorable reaction you must let your people know of your intentions. Sampling should be done at randomly selected times, and the men should not be aware of when the sampling is made.

In the case of research and development people, ingenuity is required, as how to prepare a history-and-goal chart is not as obvious as for production work. However, a schedule of the programmed work, hung on the wall, showing "what and when", for each individual will do wonders.

Skousen considers ten samples for each man in a ten-man group, or 30 samples for an individual, to be a minimum to give significant result. He ended with some worthwhile truisms: People hate to work unless it counts. Give people something to shoot for. We always seem to do one-fourth of a project in 80 percent of the time, and the rest in 20 percent. In other words, we never have time to do the project right, but always have time to do it over.

More news from California

Organic moderated reactors will play a large part in the future picture of power reactors, predicted A. R. Conant, at the **Southern California Section** (*Frederick G. Sawyer*) in February. Conant, manager of Heat Transfer Fluids Sale and Evaluation at Dow Chemical, pointed out that present heat transfer fluids under consideration in the development program of such reactors are terphenyls and biphenyls. Isopropyldiphenyl is good in this service, but too high priced. Diphenyl oxide is not suitable, because of its high neutron cross section and resultant radioactivity when used as an organic moderator.

The 1959 Spring Lectures on Reaction Kinetics, a series of five, was held during the month of April by the **New Jersey Section** (*Robert J. Boyle*). Two of the lectures, given by H. Hulburt of American Cyanamid were:

continued on page 150

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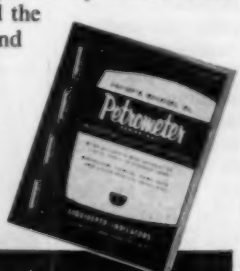

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local sections

from page 148

Principles of Kinetics and Interpretation and Application of Data. Other aspects of the subject taken up were Catalysts in Chemical Reaction, E. Soloman, M. W. Kellogg; Transport Problems in Reactors, H. E. Hoelscher, Johns Hopkins University; and Principles of Reactor Design, H. Ogburn, Atlantic Refining.

Small space rockets instrumented to telemeter back to earth data from 100 separate information channels would yield as much useful data as could be obtained from a manned satellite space station, in the opinion of Herbert Friedman. The head of the Electron Optics Branch, Naval Research Laboratory, addressed the **Philadelphia-Wilmington Section** (*B. A. Rausch*) in February.

Civilizations are judged by their engineering accomplishments, stated R. A. Charpie to the **Charleston Section** (*N. R. Kouba*) in March. His talk was a philosophic discussion of energy and man's future. Charpie emphasized the importance of the development of energy sources such as sun, sea, wind, and thermonuclear reaction. The Section's March meeting was devoted to human factors engineering. Speaker was Earl Davy of the Chemical Warfare Laboratory. . . .

A run-down on recent developments in fluid mixing technology was given the **Maryland Section** (*Philip Messina*) in January by J. Y. Oldshue. A desired fluid regime is the separation of mixing problems to those involving mass transfer, as compared with those which are merely physical dispersions, he said. A great deal of flexibility is available in scaling up mixer designs by varying the ratio of the impeller diameter to the tank diameter. Oldshue, in addition, detailed the development of quantitative criteria for determining mixer performance and some of the problems involved in scale up mixers.

The cheapest process yet studied for converting saline water to fresh is twice as expensive as the price of household water, according to past-president B. F. Dodge, Yale University. Dodge, who is now connected with the government research program on the problem, spoke to the March meeting of the **Bartlesville Section** (*Leo J. Dagley*). Cost is $1.50 per 1000 gallons, as opposed to 30¢ to 80¢ per 1000 gallons for household water. The government's research grant program is studying vapor compression, solar evaporation, multiple

continued on page 151

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from page 150

effect evaporation, freezing and crystallization processes, solvent extraction, osmosis and osmionic techniques. Great confidence is expressed that one or more of these processes would soon be developed to a competitive level with fresh water processing.

A Detroit area senior high school student was honored as winner of the Harvey M. Merker Award by the **Detroit Section** (*Clifford Armstrong, Jr.*). John W. Schiller's catalytic smoke

John W. Schiller (center) stands with the model that won him the Harvey W. Merker Award in Detroit. On the left is Merker, a retired Parke-Davis executive, right is R. A. Curtis, chmn. of Detroit Section.

burner for air pollution control, displayed at the Metropolitan Detroit Science Fair, gained him the citation. Schiller was presented with a certificate and a check for $100 at a section dinner meeting in May.

The newly instituted award, named for Harvey Merker, retired Parke-Davis executive, in recognition of his service to the profession, is given annually to the area high school student who shows the most promise and interest in chemical engineering.

Merker, in making the presentation, remarked that the important discoveries made by young scientists in the past serve as encouragement to present day students of science.

Also meeting

The **Detroit Section** (*Clifford B. Armstrong*) heard F. C. Standiford of W. L. Badger talk about the problem of converting saline water to potable, with illustrations from pilot plant experiments . . . Chemical engineering students from Pitt, West Virginia and Carnegie Tech were invited to the **Pittsburgh Section** (*V. N. Hurd*) Annual Student Night in March . . . At the April **Western Mass. Section** (*Kenneth Cashin*) the annual joint meeting with the University of Massachusetts Student Chapter took up the question of Space Medicine . . . Ladies' Night was the occasion for a lecture on medieval and renaissance painting at the **Midland Section** (*Ronald L. Johnson*) in March . . . Another ladies night devoted to an un-chemical theme, a member of the Boston Wine and Food Society talked to the **Ichthyologists** and their ladies about flavor . . . Characteristics required of fuels to be used in different types of missiles was explained to the **Alton-Wood River Section** (*C. E. Knipping*) in February. Speaker was Wilbur A. Riehl, of Army Ballistics Agency, in a speech on Chemistry and Missiles . . . A panel discussion at the **Rochester Section** (*Charles R. Adler*) in March, investigated the effect of manufacturing variables on product quality in planning experiments . . . A description of the pulp-making process and some of the problems encountered foaming in evaporators, fluid flow and heat transfer, taken up, at the **East Tennessee Section** (*James E. Williams*) in March . . . The necessity for continued chemical engineering research in the field of solid state materials was emphasized by Harry G. Drickamer at **Northeastern New York Section** (*W. L. Robb*) in February. He talked about the possible effects of pressures on the structure of solids . . . The recently constructed parts of Diamond Alkali plant near Houston inspected by **South Texas Section** (*William G. Domask*) members. Included in trip was a new mercury cell plant using the largest De Nora cells and the largest Germanium rectifiers in the world . . . Among meetings addressed by Donald L. Katz, head of A.I.Ch.E. are: **East Tennessee Section** (*James E. Williams*), in February. Talk was on natural gas industry. In March, he appeared before the **Nashville Section** (*Robert D. Brown*), talking on Heat transfer through finned tubes. The **Charleston Section** (*N. R. Kouba*) heard Dr. Katz in February. Also featured at the meeting was a panel discussion of the problem of water.

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Max E. Bretschger, former president of Becco, has been awarded the Schoellkopf Medal for 1959. Bretschger, was given the award for his leadership in research and development which resulted in the production of concentrated hydrogen peroxide by the ammonium persulfate process, and for his guidance in the establishment and growth of technical education at the two year college level. The award is made by the Western New York section of ACS.

Bretschger worked in Switzerland, Italy and Germany in the chemical industry until 1926 when he became associated with the Buffalo Electro-Chemical Company at Buffalo, N. Y. Elected president of the company in 1952, and now retired, he functions as senior technical adviser of the division.

Bretschger's part in developing concentrated and anhydrous hydrogen peroxide has been instrumental in improving techniques for rocket propulsion and organic synthesis requiring this oxidizing agent.

Bretschger was a member of a three-man team which the United States Government sent overseas in 1945 to survey the hydrogen peroxide industry in occupied territories.

A member of the board of trustees of Erie County Technical Institute, he is credited with contributing to a doubling in enrollment of the Institute since its inception in 1946.

Bretschger received the Professional Achievement Award from the Western New York Section of A.I.Ch.E. in 1956.

Jerry McAfee has been elected to the board of directors of Callery Chemical Company. He is vice president of engineering in the manufacturing department of Gulf Oil, which recently increased its financial interest in Callery to 50 percent. Current vice president of A.I.Ch.E., McAfee has been with Gulf Oil for fourteen years. He was selected in 1953 as one of the 100 Pittsburgh Leaders of Tomorrow by the Pittsburgh Chamber of Commerce and *Time* magazine.

Clarke L. Coldren becomes manager of Shell Pipe Line Corp.'s technical development laboratory in Houston. He steps up from the post of engineer at Shell Development's Emeryville, California, laboratories. Also at Emeryville, **H. A. Kingsley** was appointed supervisor in the chemical process engineering department at the Research Center.

Recent appointments to AviSun Corp. from Sun Oil are: **Edward T. Severs,** product manager, polymers; **Neil A. Hansen** and **James C. Warren,** product engineers, polymers. All three men are in the commercial development division. **Donald Fiedler** comes to AviSun from American Viscose, taking over the job of product manager, Research and Development Division. At American Viscose, **A. W. Hogeland** moves into the post of chief plant engineer at Fredericksburg, Va., in changes brought about by transfers to the newly formed AviSun Corp., co-owned affiliate of American Viscose and Sun Oil.

Robert C. Canapary named product manager for petroleum industrial chemicals in the Industrial Division of National Aluminate Corp. Canapary joined Nalco in 1956, after having been associated with Quaker Chemical Products and Esso Research and Engineering.

Edward J. Fradkin, project manager with the Scientific Design Company of New York, has left for a six month assignment in Japan.

Joseph L. McCarthy appointed dean of the University of Washington's Graduate School. McCarthy is now on professional leave from the Chemical Engineering Department at the University to conduct research at the University of Cambridge. He assumes his new post on July 1. A graduate of the University, McCarthy received his Ph.D. in chemistry from McGill University in Montreal. The new dean has headed the Pulp Mills Research Project, administered under the graduate school, since its establishment in 1944. More than $500,000 has been received in grants by the project for studies in the search for profitable uses for lignins and other by-products of pulp and paper industries.

McCarthy takes over direction of the graduate school from Henry A. Burd, who came out of retirement in 1955 to become acting dean of the school.

Herbert Hirschland elected to the newly created post of vice president of Metal & Thermit, Commercial Development Division. Hirschland has been associated with the company throughout his entire career, both in sales and research.

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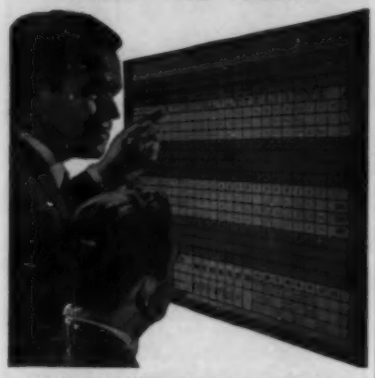

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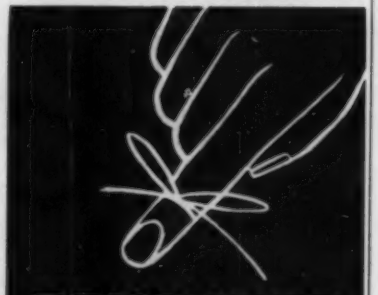

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people in management & technology

Roman Chelminski joins Singmaster & Breyer, New York metallurgical and chemical process engineers, as an associate. He had previously been a senior partner in Knowles Associates for twelve years. Chelminski, in addition to holding several patents, is co-author of Uranium Ore Processing, official U.S. government contribution to the Second International Conference on Peaceful Uses of Atomic Energy, held in Geneva in 1958.

Dixon Johnson named vice president of W. Alec Jordon Associates, chemical marketing consultants and technical public relations firm. Johnson, a specialist in nuclear and chemical developments, was formerly vice president of Molesworth Associates. He is a former newspaper writer and editor, and was for several years director of public relations of the Oak Ridge Institute of Nuclear Studies in Oak Ridge, Tennessee. Another addition to Jordan is **Robert L. Davidson,** who has joined the firm as executive associate. Davidson, who is author of "Successful Process Plant Practices," was formerly senior editor of *Petroleum Week.*

Robert Cox and **Arthur S. Nicholas** have formed a new corporation, The Leon Chemical Industries, Inc. Located in Warren, Michigan, the firm's main products will be acrylic coatings for glass and metals, paint intermediates and formulated epoxy.

Maynard C. Wheeler elected president of Commercial Solvents Corp. Wheeler, who started with the company in 1923, was senior vice president of the firm. He is also a director and vice president of Northwest Nitro Chemicals, Ltd., Canadian fertilizer manufacturing affiliate of the company.

Sherwood B. Seeley elected vice president in charge of research for Joseph Dixon Crucible Co., Jersey City, N.J. He was formerly technical director of the company. Additions to Monsanto's staff: **Jerry B. Roach,** Engineering Department, and **Keun Y. Kim,** Research Department at Inorganic Chemicals Division, St. Louis.

Continued on page 154

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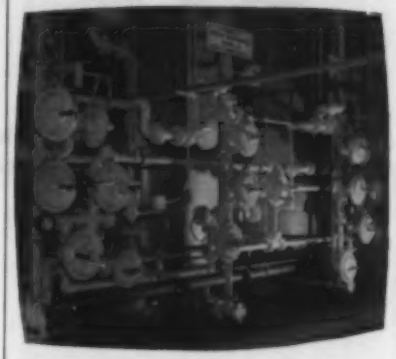

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people in management & technology

from page 153

New vice president and assistant to the president at Dixon Chemical & Research is **Robert D. Buckalew.** He joins Dixon Chemical from Rodger & Gallet, where he was vice president of marketing.

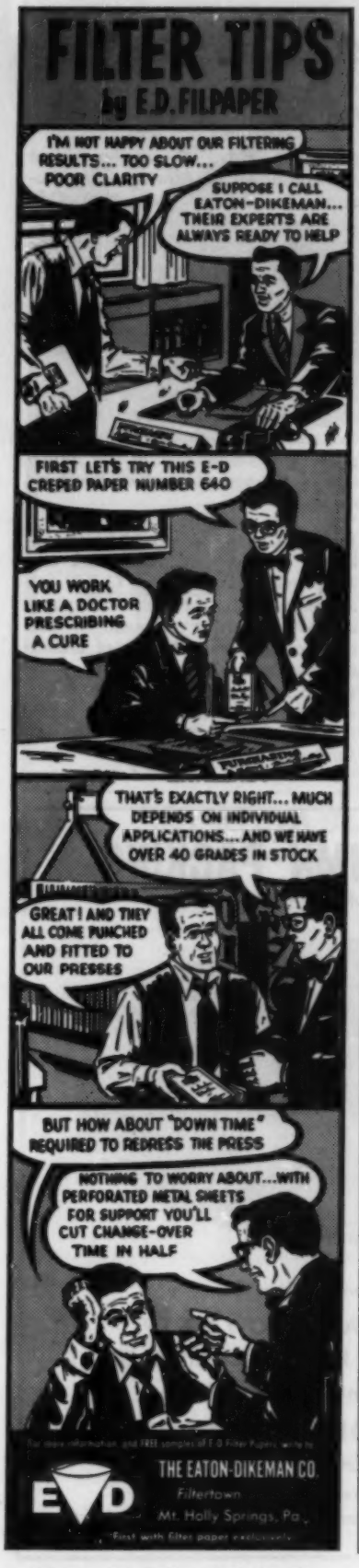
Thomas B. Drew, member of the Chemical Engineering Department and chairman of the nuclear engineering program at Columbia University, appointed visiting professor of chemical engineering at M.I.T. for the academic year 1959-60. During this time, he will be on sabbatical leave from Columbia.

Milton Stern is winner of the Electrochemical Society's Prize to Young Authors for 1958. Stern, who is technical supervisor of the Metal Research Group at Union Carbide Metals, Niagara Falls, New York, was selected for the award in recognition of his paper, The Mechanism of Passivating-type Inhibitors. Stern recently made the discovery that the addition of small amounts of palladium, or other noble metals, adds considerably to the corrosion resistance of titanium.

Charles E. Webber was elected president of the Natural Gasoline Association of America at its 38th Annual Convention in Dallas, Texas, in April. Webber, who is technical advisor to the vice president of Sun Oil at Philadelphia, has been with the company since the end of World War II, except for a brief period when he served as director of the Natural Gas Production and Processing Division of the Petroleum Administration for Defense in Washington. Webber received the Hanlon Award, top honor in the gas processing industry, in 1957.

Headlining the list of speakers at the three day convention was **Donald L. Katz,** who presented the concluding address at one of the general sessions. He spoke on advances in the nuclear field.

Aimison Jonnard joins U.S. Industrial Chemicals as assistant manager, polymer planning and applications. Jonnard previously was with Shell Chemical as manager of the Chemical Market Analysis Department. He has also conducted research on plastics and resins at the Mellon Institute of Industrial Research.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people in management & technology

James D. Moore named plant manager at Vitro's uranium mill in Salt Lake City, Utah. Moore joined Vitro in 1951 as a chemical engineer.

Cedomir M. Sliepcevich, associate dean and chairman of the University of Oklahoma School of Engineering, received the $3000 Ipatieff Prize in Chemistry. The prize is awarded every three years to a scientist under 40 in recognition of outstanding chemical experimental work in the field of catalysis or high pressure. Sliepcevich addressed the American Chemical Society on Chemical Processing at Extreme Conditions at its convention in April, when he was presented with the prize. Sliepcevich was cited for his contributions to design of chemical process equipment for service at extreme conditions, and for his experimentations in catalytic reactions at elevated temperatures. He is the author of more than 40 papers and in addition to his academic work, also acts as consultant to the industry.

people in marketing

Harold R. Kibby transferred to the new sales office of Buflovak Equipment Division, Blaw-Knox, in Houston, Texas. He will represent the company at the new location.

Ernest S. Robson appointed eastern regional sales manager for Monsanto. He succeeds **James A. Singmaster,** who has been appointed to the company's Corporate Planning Group at St. Louis.

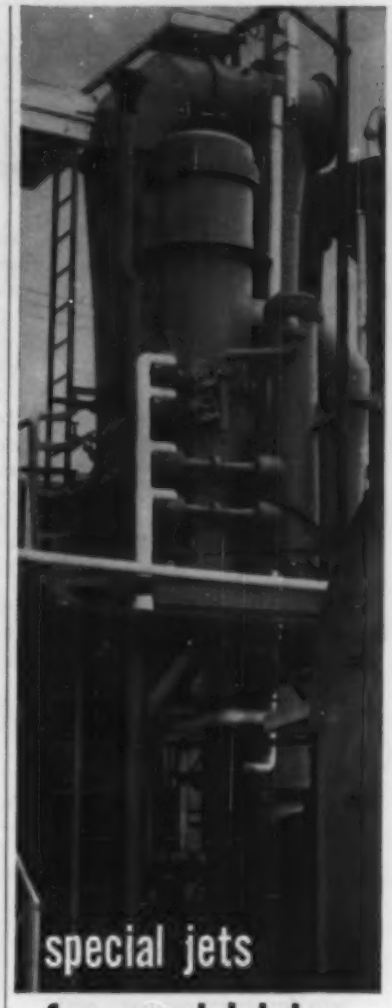
John F. Flynn transferred to the New York district of Union Carbide Chemicals as technical representative.

John R. Draves joined Goodrich-Gulf Chemicals as a sales engineer, assigned to the New England area.

Herman R. Woodall promoted to the new position of assistant director of sales for chemical and specialty products at Du Pont. Woodall, a veteran of more than twenty years service with the company, is with the Wilmington office.

In key organizational changes at Heyden Chemicals, three product sales managers were named. They are **T. R. Aalto,** Fine Chemicals; **E. L. Barkley,** synthetic resin chemicals; **T. H. Risch,** organic intermediate chemicals.

continued on page 156



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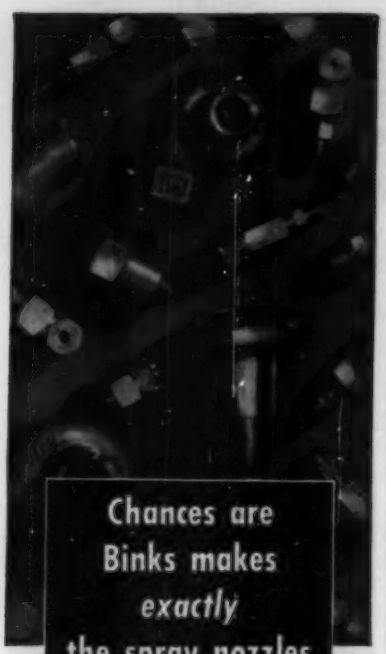

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people in marketing

from page 155

Orlen E. Baker becomes manager of the newly created Petroleum Sales Division at Infilco. Baker has made extensive studies of water and brine treatment for secondary recovery of oil. Headquarters are in Tucson, Arizona.

James S. Anderson moves over to the position of vice president and general manager of the Tubular Products Division at Babcock & Wilcox. He is located at Beaver Falls, Pa.

Donald R. Meserve appointed sales manager of the Organic Coatings Division of Metal & Thermit. Meserve has, for the last seventeen years, worked on research and development, technical service, production and sales for the Company.

Ralph O. Williams joined the sales staff of A. Gross & Co., New York manufacturing firm. Working out of Charlotte, N. C., Williams will handle sales and technical service for the company in the Carolinas, Virginia and Eastern Tennessee.

Necrology

Marvin J. Udy, 67, vice president and consultant for Strategic-Udy Processes, Inc., Niagara Falls, N. Y. Udy is credited with developing the first commercial processes for the refining and utilization of chromium. For this, he was awarded the Schoellkopf Medal in 1948. In 1956, he received an honorary degree from Alfred University, in recognition of his achievements in the field of electric furnace research. Most recently, Udy's work on continuing development of selective reduction methods applied to low grade ores culminated in the formation of the company which bears his name.

John B. Calkin, 55, president of Calkin & Bayley, Inc., New York city industrial consulting firm. Calkin was associated with the pulp and paper industry as paper technologist and chemical engineer. Author of numerous papers on paper technology, he served for years as consultant to the chemical and chemical process industries. He became head of Calkin and Bayley in 1957.

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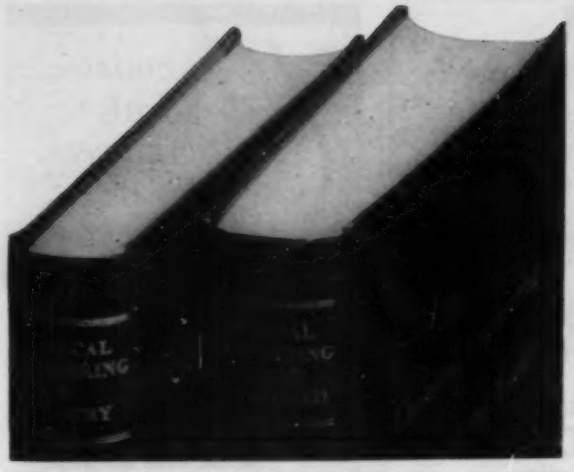

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continued on page 160

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(continued from page 159)

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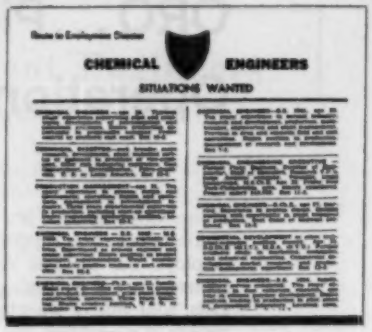
ADVANCE INFORMATION

The Situations Wanted portion of this Classified Section is preprinted and mailed a few days in advance of publication, to Employment Directors. Send names of individuals who should be on mailing list to: Miss E. Adelhardt, Chemical Engineering Progress, 25 W. 45th Street, New York 36, New York.

CHEMICAL ENGINEERING TEACHING POSITIONS AVAILABLE

A list of chemical engineering teaching positions in schools and universities in the United States and Canada on Feb. 20, 1959 may be obtained from the Secretary, A.I.Ch.E., 25 West 45th Street, New York. Salary data and rank of position are given.



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Advertisement in the Classified Section are minimum of four lines accepted. Box number counts as two words. Advertisements payable in advance at 24c a word, with a average about six words a line. **Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates.** Prospective employers and employees in using the Classified Section generally agree that all communications should be acknowledged as a matter of courtesy but recognize circumstances where secrecy must be maintained. Answers to advertisements should be addressed to the box number. Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Adertisements for this section should be in the editorial offices the 10th of the month preceding publication.

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See additional display advertisements on page 27.

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INDEX OF ADVERTISERS

	Page
Abbe, Inc., Paul O.	121
Aerofin Corporation	112
Air Preheater Corp.	147
Air Products, Inc.	131
Aldrich Pump Co., The	99
Allis-Chalmers	113
American Air Liquide	139
American Hard Rubber Co.	26
American Machine and Metals, Inc.	30-31
Atomic Energy of Canada Limited	13
Badger Mfg. Co.	23
Baker Perkins Inc.	28
Barco Manufacturing Co.	24
Bartlett & Snow Co. The C. O.	Inside Front Cover
Binks Mfg. Co.	156
Blaw Knox Company Buflovak Equipment Div.	6-7
Bowser, Inc., Process Filters Div.	129
Brabender Instruments Inc., C. W.	152
Carlson, Inc., G. O.	120
Chempump Corporation	123
Chicago Bridge & Iron Co.	29
Colorado Fuel & Iron Corp., The	135
Cooper-Bessemer Corp.	124-125
Croll-Reynolds Co., Inc.	10
Dean Brothers Pumps Inc.	34
Dean Thermo-Panel Coil Div., Dean Products, Inc.	161
Dorr-Oliver Incorporated	106-107
Downingtown Iron Works, Inc.	32
Duralab Equipment Corp.	88
Eaton-Dikeman Company	155
Eco Engineering Co.	25
Eimco Corporation	90
Elgin Softener Corp.	150
Ellicott Fabricators, Inc.	119
Engineers & Fabricators, Inc.	115
Filtration Engineers Div. of American Machine and Metals, Inc	30-31
Fletcher Works, Inc.	12
Flexrock Company	161
Foxboro Company, The	144-145
General American Transportation Corp.	81
Goulds Pumps, Inc.	109
Graphic Systems	153
Graver Tank & Mfg. Co.	111
Greene, Tweed & Co.	153
Gump Co., B. F.	5
Haveg Industries, Inc.	82-83
Hetherington & Berner Inc.	136
Heyl & Patterson Inc.	105
Hubbert & Son, Inc., B. H.	148
Hudson Engineering Corp.	19-20
Illinois Water Treatment Co.	153
Industrial Process Engineers	110
Ingersoll-Rand	14, 150
Jet-Vac Corp., The	155
Kellogg Co., M. W.	101
Koven Fabricators, Inc.	122
Lapp Insulator Co., Inc.	9
Lawrence Pumps Inc.	114
Lehmann Co., Inc., J. M.	154
Liquid Solids Separation Specialists Div. of American Machine and Metals, Inc.	30-31
Mixing Equipment Co., Inc.	Outside Back Cover
National Carbon Co., Div. of Union Carbide Corp.	87, 103
National Engineering Co.	141
Niagara Filters, Div. of American Machine and Metals, Inc.	30, 31
Niagara Blower Co.	151
Oldsmobile Division	137
Packed Column Corp.	156
Parsons Company, The Ralph M.	Inside Back Cover
Patterson-Kelley Co., Inc.	132-133
Petrometer Corp.	149
Pittsburgh Coke & Chemical Co.	94
Process Filters Div.	129
Safety Industries, Inc.	154
Sargent's Sons Corp., C. G.	118
Schutte & Koerting Co.	146
Sharples Corp., The	117
Simpson Mix-Muller Div.	141
Stanford University Press	138
Stephens-Adamson Mfg. Co.	11
Stratford Engineering Corp.	18
Swenson Evaporator Co., Div. of Whiting Corp.	21
Swift Glass Div., Swift Lubricator Co., Inc.	146
Syntron Company	138
Taylor & Co., W. A.	136
Tennessee Corp.	148
Texas Gulf Sulphur Co.	89
Tolhurst Centrifugals Div. of American Machine and Metals, Inc.	30-31
Turbo-Mixer Div., General American Transportation Corp.	81
Union Carbide Corp. National Carbon Co.	87, 103
U. S. Industrial Chemicals Company, Division of National Distillers and Chemical Corporation	85-86
U. S. Stoneware	36
Warren Pumps, Inc.	130
Waukesha Foundry Co.	157
Western Supply Company	93
Whiting Corporation	21
Wickwire Spencer Steel Div. of Colorado Fuel & Iron Corp., The	135
Wiley & Sons, Inc., John	149
York Co., Inc., Otto H.	4

C.E.P. Advertising offices

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News and Notes of A.I.Ch.E.

The Texas Chemical Engineer—The Student Chapter at the University of Texas has just published Volume 1, No. 1 of *The Texas Chemical Engineer*, a collection of technical articles, discussions of professional responsibilities of chemical engineers, etc., edited by H. Maurice Doke. This first issue is dedicated to Ken Kobe, Professor of Chemical Engineering at Texas for seventeen years, who died last November. W. A. Cunningham, a past director of A.I.Ch.E., is adviser to the publication.

The Professional Development News—Bill Keppler and Bob Ghelardi have just issued Volume IV, No. 3, of *The Professional Development News*, a publication of the Professional Development Committee. Any members of A.I.Ch.E. who would like to see a copy of this may get one from Bill Keppler at Merck, Sharp & Dohme International Division, 100 Church Street, New York. Bill and Bob tackle the problem of engineering registration and are interested in receiving pros and cons on the subject. They should be sent to Bill.

Yale Seniors will be eligible for an annual award given by the New Haven Section of A.I.Ch.E. for achievement in chemical engineering course

work and indication of interest in the chemical engineering field. The award, as described by John A. Tallmadge, Chairman of the Section, will consist of the payment of the Associate Membership dues for the winner for one year—unless the winner is going into graduate work, in which case subscriptions to A.I.Ch.E. publications will be substituted.

Maryland Section of A.I.Ch.E. received kudos from Bob Taylor, Chairman of the Chemical Industry Committee of Maryland, for its cooperation in Chemical Progress Week, according to A. W. Taff, Chairman of the Section. "No small part of the success this year," said Taylor, "was the result of the cooperation received from the Local Section of A.I.Ch.E." In Baltimore, fifteen industrial and professional people appeared on ten TV shows during the week, and on radio four industry representatives were interviewed and additional recorded spot announcements were made over five stations.

Attention, Program Chairmen—The Atomic Energy Commission's film library has just published two lists of available films pertaining to atomic energy—one list on a popular level, suitable for Ladies' Night; the other on a professional level, useful for supplemental programing at regular Local Section meetings.

Presidential Visits—This spring President Don Katz will visit twenty-eight sections of A.I.Ch.E., with more coming up as the fall programs get underway.

Excellent publicity has resulted from President Katz's talks. As a typical example, G. E. Merryman, Jr., sent a clipping of an extensive interview which appeared in the Charleston, West Virginia, *Gazette Mail* on the relative positions of coal and natural gas.

Book exhibit for A.I.Ch.E.—Council has okayed a new idea for meetings, a book exhibit to present recent titles in chemical engineering and allied engineering fields of interest to the members. The exhibit, which will be under the direction of Joel Henry, Assistant Secretary, will make its debut at San Francisco.

Lecture Series—Two Local Section lecture series have come to my attention recently—one by the New York Section, covering chemical reactor design, and the other by the New Jersey Section, covering reaction kinetics.

Membership Drive—According to Sam West, Vice-Chairman of the Membership Committee, the Southern Division of the Committee walloped the North for the first time in recently recorded history. Irv Leibson, the commander of the Southern forces, was very modest in accepting the victory and is lining up ammunition to continue it for the rest of the year.

Regarding membership and membership activities, all A.I.Ch.E. members have a stake in interesting nonmember chemical engineers in their professional organization.

H. A. Holcomb of the South Texas Section at the time of the visit by President Katz sent the following memorandum to the members: "You as members of the A.I.Ch.E. belong to a select group and whether you are aware of it or not are in effect members of the Membership Committee. The effectiveness with which you function as such depends in large part on whether or not you are presenting to nonmembers a picture of professionalism which will induce them to follow your leadership. The coming meeting will give you an excellent chance to expose some nonmember to a broader picture of the cream of the chemical engineering profession."

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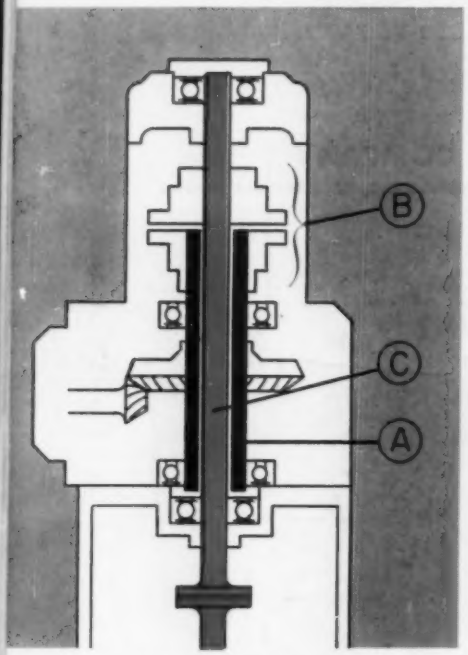

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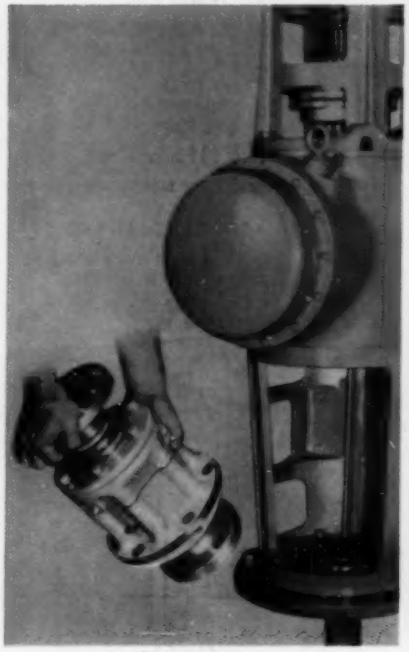

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